A STATEWIDE EXAMINATION OF ATTITUDES TOWARD SCIENCE AMONG ILLINOIS STUDENTS IN GRADES 5-12

BY

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DISSERTATION

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Abstract

The present study investigated precollege students' perceptions and attitudes about science, as well as their intentions regarding the continued study of science in the future. The central research questions were: "What is the landscape of Illinois students' attitudes toward science across their school experience?" and "To what extent do school characteristics, including the attributes of classroom teachers, influence student attitudes toward science across the state of Illinois?" To address these research questions, the first phase of this study involved the refinement and validation of a self-report student instrument, the US-ASSASS, which assessed student attitudes toward science based on a theoretical framework drawn from the theories of reasoned action and planned behavior.

In the second phase of the study, a representative statewide sample of 1,442 students in grades 5-12 were surveyed about their attitudes toward science using a cross-sectional design. Cross-sectional design was ideal because it allowed data to be collected from students of various ages, and over a large geographical area yielding a wide variance among respondents (e.g., in terms of socioeconomic status). In an effort to allow for equal representation of students across the state, participant schools were selected randomly from each of six geographic regions identified in Illinois. Students completed the 59-item US-ASSASS, along with background items, online. Confirmatory factor analysis was computed using the 1,291 responses collected from students in grades 5 through 10. A five factor structure was refined that was consistent with the underlying theoretical model and the finalized 30-item instrument that demonstrated acceptable statistical fit with a RMSEA of 0.04, a CFI of 0.95, and a non-normed index of 0.95.

In addition to student data, information was obtained from 65 of a total of 78 classroom sections and respective schools from which student data were collected. Teachers' responses to the Science Teacher Survey, along with data compiled from the Illinois Report Card and the

National Center for Educational Statistics, allowed for the consideration of several group-level variables (e.g., teacher education, school funding, and community type). These variables were systematically explored and used to create a multivariate multilevel model to characterize students' attitudes toward science and related factors. Inferential statistics, coupled with descriptive statistics, revealed that students' attitudes toward science declined as they went up their grade levels. A final statistical model was computed from responses collected from students in grades 5-10 that portrays significant declines and other effects. However, the students in the sample who persisted in science until grades 11 and 12 reported high attitudes toward science according to the descriptive statistics presented. It is also positive to note that students' who reported high frequency of talking with family about school and/or a high self-perception of science ability, had improved scores on all US-ASSASS factors.

Illinois students' decline in attitudes toward science, through grade 10, is consistent with prior literature, and suggests the need for future research to ascertain whether this decline is disproportionate for science, compared to other core subjects (e.g., language arts). Additionally the present study gives some legitimacy to the constructs proposed by the theories of reasoned action and behavior, and it is prudent for future efforts to establish the extent and consistency between students' intention to pursue science in the future and their future decisions to engage in science.

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TABLE OF CONTENTS

Chapter I

The Problem

Introduction

Rising above the Gathering Storm (National Research Council [NRC], 2007) emphasized that the quality of life in the United States is largely dependent on the continued production of knowledge and innovation in science and technology. The National Science Board (NSB, 2001) voiced the same message, stating that "advances in science and engineering . . . determine economic growth, quality of life, and the health and security" for our nation (p. 7). The sciences, now more than ever, are directly connected to the viability and sustainability of all crucial foundations of prosperous nations. For modern societies, now heavily reliant on science and technology, to continue to flourish, they need citizens who are literate in, and able to engage with, these domains. To meet current and future demands in science, technology, engineering, and mathematics (STEM), an educated, innovative, and motivated workforce is the most important resource (NRC, 2007).

The Endless Frontier, Vannevar Bush's historic report (Bush, 1945) addressed the question of how to maintain high levels of scientific knowledge production in the United States, with an emphasis on research and development, in the postwar era. Bush noted that a first rate science education is necessary to sustain this ambition and explained:

> The responsibility for the creation of new scientific knowledge rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research. While there will always be the rare individual who will rise to the top without the benefit of formal education and training, he is the exception and even he might have make a more notable contribution if he had the benefit of the best education we have to offer. (p. 23)

Bush's words, and the nature of his report, marked the beginning of a tradition in which advocates regularly stress the importance of what now is referred to as STEM education. Often adopting a tone of urgency, these reports gained momentum in the 1980s as a response to the shortage of STEM workers (NSB, 2010). This was notably illustrated by *A Nation at Risk* (National Commission on Excellence in Education [NCEE], 1983), depicting the harsh reality that students in the United States had fallen to mediocrity compared to their international competitors. To combat this situation, the NCEE made several recommendations aimed at strengthening educational programs, particularly in science and technology. However, despite the cautionary words in these historical reports, and the recommendations offered for bolstering educational programs in science and technology, it seems that STEM education, pipeline, and workforce issues still threaten the prosperity and competiveness of the United States.

Science education has two broad functions, to instruct students—future citizens—about science and to cultivate the next generation of scientists (Deboer, 1991; Millar & Osborne, 1998). Both aims are important, to enable participation in a society reliant on science and to maintain the health and prosperity of the scientific enterprise. Evidence, however, suggests that the latter aim is being unfulfilled with majority of students failing to engage with STEM at the post-secondary level (e.g., United States Department of Labor, 2007), along with reports that interest among young people for pursuing scientific careers is declining (e.g., Schreiner & Sjøberg, 2004). Recently, out of the 1.8 million American high school students from class of 2013 who provided responses to questions on the ACT (2014) "interest inventory," *The Condition of STEM* 2013 indicated that more than 150,000 had an inherent interest in STEM, but did not have plans to major in a STEM field in college or pursue a STEM-related career. National leaders, policy-makers, and educators have reached a general consensus that the number of students studying science and pursuing science-related fields is fleeting (George, 2006). Thus, in addition to overarching concerns with scientific production in the United States, there are a growing number of questions about the factors, such as school science education, that influence precollege students' decision to pursue future careers in STEM. Such questions have made student attitudes toward science a matter of great concern for society and policy-makers (Tytler & Osborne, 2012).

Research on Student Attitudes toward Science

Attention to students' attitudes toward science has historically increased in response to periods wherein students seem to exhibit greater disinterest in, and even disdain for, science and technology (Ormerod & Duckworth, 1975). Recent publications indicate that students are less interested in pursuing scientific careers (e.g., Convert, 2005; Jenkins & Nelson, 2005; Osborne & Collins, 2001; Schreiner & Sjøberg, 2004; Sheridan, 2006; Sudas & Iurasova, 2006). In addition, several studies report that students' attitudes toward science decline as they get older. These attitudes start to decline in the first year of elementary school (Murphy & Beggs, 2003; Pell & Jarvis, 2001) and decline more sharply as students approach secondary school (Farenga & Joyce, 1998; Kelly, 1986; Pell & Jarvis, 2001; Speering & Rennie, 1996). Such trends are reminiscent of historical calls to action and demand a response. More than ever, attitudes stand to play a crucial role in combating disconcerting trends in student preferences as the development of positive attitudes toward science can motivate student interest in science learning and science-related careers (Carey & Shavelson, 1988; Keeves, 1975; Norwich & Duncan, 1990).

Researchers have studied student attitudes with the underlying hypothesis that they help to steer career choice and school performance (e.g., Cannon & Simpson, 1985; Germann, 1988; Hill, Atwater, & Wiggins, 1995; Hough & Piper, 1982; Rennie & Punch, 1991; Wyer, 2003). Osborne, Simon, and Collins (2003) contended that the promotion of favorable attitudes toward science, scientists, and learning science continues to be a viable strategy for increasing student engagement with scientific disciplines. Nonetheless, previous evidence suggests that relatively few students have developed the attitudes necessary to foster their involvement in STEM. The preferences exhibited by the majority of students in the United States are certainly the product of a number of contributing factors. Entrenched, systemic variables ranging from the educational (e.g., Bevins, Brodie, & Brodie, 2005) to the cultural and social (e.g., Aikenhead & Jegede, 1999; Costa, 1995) probably influence student interest to some degree. It also is very likely that student experiences with the teaching and learning of science in precollege classrooms works to shape their personal preferences (Patrick & Yoon, 2004).

Assessing and Interpreting Attitudes Toward Science

In an effort to understand the complexities of the situation described above, it is essential to assess students' attitudes toward science and examine the ways in which these attitudes change during students' years of formal schooling. Extant measures for assessing student attitudes toward science are quantitative, and most employ Likert-type scales intended to measure the strength of individuals' attitude (Fishbein, 1967, as cited in Germann, 1988). A review of the literature raises three serious, and related, concerns about attitude instruments. The first concern, highlighted by Blalock and colleagues (2008) in their review of 66 instruments relating to attitudes, is that there are numerous cases in which extant instruments fail to meet the minimum standards of modern psychometric evaluation. Second, many of the instruments that continue to be the basis for recent and current research were developed over 30 years ago, and do not reflect recent advances in psychometric (e.g., Fraser, 1978; Germann, 1988; Moore & Sutman, 1970; Simpson & Troost, 1982). Finally, existing instruments have been criticized for lacking well-articulated theoretical frameworks, which may threaten their validity (Messick, 1989). Taken together, these concerns stymie research progress in this domain given the general absence of robust, valid, and reliable measures of student attitudes toward science. Concerns related to anchoring the development of instruments in adequate theoretical frameworks must be resolved first since it is cornerstone to the development of robust instruments.

An additional major limitation is that almost all existing instruments aimed at assessing students' attitudes toward science were designed to target either a single grade level (e.g., Catsambis, 1995) or a restricted range of grades, such as middle or high school (e.g., DeBacker and Nelson, 2000). Research studies making use of these instruments, while surely useful, were somewhat limited as they could not allow for meaningful interpretation and robust conclusions when it came to addressing questions related to changes in student attitudes across their K-12 school experience.

When it comes to theoretical frameworks, researchers aimed at understanding attitudes toward science have been drawn to social psychological models as means of understanding student social reality (Crawley & Koballa, 1994). The theory of reasoned action (Fishbein & Ajzen, 1975) represents a unifying and systematic conceptual framework grounded in the assumption that the affective, cognitive, and behavioral aspects of attitude interact in a causal and unidirectional manner (Butler, 1999). Science education researchers have often attempted to understand students' decision to engage with science employing the theory of reasoned action (e.g., Crawley & Black, 1992; Crawley & Coe, 1990; Crawley & Koballa, 1992) to examine intention rather than attitude. Koballa (1988a) emphasized that a primary goal of measuring students' attitudes toward science is to *predict* student behaviors, explaining that many of the concerns related to science engagement involve students behaving in a particular manner (e.g., enrolling in additional science courses). Recent reviews (e.g., Osborne, et al., 2003; Nieswandt, 2005) have supported this shift and acknowledged the theory of reasoned action as the dominant theory in the field. The most recent revision of this theory is known as the theories of reasoned action and planned behavior (TRAPB; Ajzen & Fishbein, 2005). However, even with the widespread recognition this theory has received, there has yet to be an instrument in this research domain that was explicitly rooted in the theory of reasoned action (and surely not, to the best of my knowledge, in the TRAPB) and validated for use in the United States. Fortunately such an instrument was recently developed for use in an international context and may serve as the basis for instrument development and validation for use within the US context.

The “Arabic Speaking Students’ Attitudes toward Science Survey” (ASSASS) was developed for the purposes of gauging Qatari students’ attitudes toward science. The instrument items were systematically selected to represent the distinct aspects described by the TRAPB (Summers, 2012), ultimately validated and refined from an initial pool of item pilot items to a 32-item instrument (Abd-El-Khalick, Summers, Said, Wang, & Culbertson, 2015). The instrument was purposefully designed to gauge student attitudes toward science across a wide-range of grades—namely grades 3 through 12—allowing for robust cross-sectional and longitudinal studies. The ASSASS addresses concerns related to anchoring instrument development in a robust theoretical framework, and use of current psychometric techniques for instrument validation, as well as targeting a wide range of school grade levels.

In order to move the field forward, and to better understand the factors that shape students’ attitudes across the K-12 ladder, emerging research should consider the usefulness of cross-sectional and longitudinal data in detecting important patterns, especially because student attitudes seem to vary with age (Farenga & Joyce, 1998; Kelly, 1986; Murphy & Beggs, 2003; Pell & Jarvis, 2001; Speering & Rennie, 1996). Cross-sectional studies, in particular, encourage the inclusion of diverse student populations from a range of backgrounds and school settings.

Statement of the Problem

The preceding sections articulate the need for further research into students' attitudes toward science as a means of examining their declining interest in pursuing STEM studies or careers. Such research, however, is hindered by a number of problems related to the assessment of student attitudes, and the examination of these attitudes among large population of students across their school science experience. First and foremost is the problem of lack of a systematically developed and validated instrument that builds on current theoretical frameworks and utilizes robust psychometric analyses. Second, concerns extend to the content of existing instruments as well, because outdated instruments may not contain items that are sensitive to the current milieu and experiences of K-12 students. Third, the restricted grades and grade range(s) addressed by extant instruments shortchanges the aforementioned and much desired cross-sectional and longitudinal studies of attitudes. The amelioration of these concerns is required to grow and develop this domain of research. Nonetheless, there has not been a concerted effort from researchers in the United States to address these obstacles.

Purpose

The present study details the validation of the ASSASS instrument for use in the United States context, explores students' attitudes toward science across the state of Illinois and gauge differences in these reported attitudes between students in grades 5 through 12, examine factors that might impact any observed patterns in Illinois students' attitudes toward science as they go through schooling. The following research questions were addressed in this study:

1. What is the factor structure for the ASSASS administered to US students, and does this structure reflect the instrument's underlying theoretical framework (i.e., the TRABP)?
2. What is the landscape of Illinois students' attitudes toward science across their school experience?

3. To what extent do school characteristics, including the attributes of classroom teachers, influence student attitudes toward science across the state of Illinois?

Significance

To researchers and scholars concerned with studying and understanding students' attitudes toward science, as well as related domains, the present study provides a new, rigorously developed instrument, which is grounded in robust theory and validated by use of current psychometric tests. Because the ASSASS instrument was grounded in the TRAPB framework, data collected in this study allowed for a critical examination of its constructs in relation to attitude assessment by means of self-report. For a wider audience, the present study provides insight into issues that have relevance nationally, as well as internationally. This study distinguishes itself from much of the extant research into students' attitudes toward science by administering a well-developed instrument to a statewide sample of students. Drawing from a cross-sectional sample of students, patterns common to this field of research (e.g., attitude toward science and attitudes toward school science) may be more apparent in a larger sample with responses from multiple grade levels. Given the role of the science teacher as a mediator of school science, teacher data collected may help to make sense of student responses and shed light on variables that influence students' attitudes toward science.

Chapter II

Literature Review

The purpose of this chapter is to argue for continued research into students' attitudes toward science and to articulate why future progress in the field is contingent on large-scale investigations that incorporate clearly articulated theoretical frameworks. To frame this discussion the history of attitude research as it relates to precollege science education is examined, focusing on major constructs and related influential factors, which have guided research in the field. This background allows for an investigation into the prominent theoretical models employed in the field and facilitates a critical discussion about past efforts to assess students' attitudes toward science. This discussion highlights concerns about both the methodology and instrumentation used in the past, while outlining changes that should be adopted for modern studies.

Overview of Attitude Research in Science Education

Since the early 20^{th} century, educational researchers have been drawn to the study of attitudes as a way of making sense of student preferences and engagement. Nearly 40 years ago, Ormerod and Duckworth (1975) noted in their review of the research literature that research into students' attitudes toward science seemed to increase in response to observed periods of student disinterest in, and even disdain for, science and technology. Historically, these periods have served as a call to arms for the investment in and promotion of STEM education as a means to secure the scientific pipeline.[1] Osborne et al. (2003) reiterate how these periods have impacted the flow of research, explaining that reports of student disinterest in science (e.g., Schreiner &

[1] The metaphor of the science pipeline is used here to represent the successive training experiences necessary for students to consider a career in science (Berryman, 1983). Hanson (1996) later distinguished four dimensions or pipelines along which students experience science: access, activity, achievement, and attitudes.

Sjøberg, 2004) in the face of increased recognition for the importance of scientific knowledge (see NRC, 2007), spurred a renewed attention to students' attitudes toward science.

With a considerable amount of emerging research which suggests the level of interest among young people for pursuing scientific careers is declining (e.g., Schreiner & Sjøberg, 2004), the current situation shares circumstances similar to previous episodes in the history of this domain. Adding to the severity of the present situation, tensions have been raised about the number of STEM positions, which will need to be filled in the near future compared to the dismal number of qualified workers currently available (National Assessment of Educational Progress, 2009). The current situation is further confounded by recent evidence (e.g., US Department of Labor, 2007) that suggests a majority of students are failing to engage in STEM at the post-secondary level. This potential shortage, which is of dire concern for the United States, has been the subject of numerous publications (e.g., *American Competitiveness Initiative* [Domestic Policy Council, 2006]; *Rising above the Gathering Storm* [NRC, 2007]) and drawn researchers to affective variables, such as attitudes, in search of answers.

A historical account of attitude research can be found in literature from psychology, sociology, and related fields. Early contributions from these fields, including Carl Jung's depiction of attitude (Jung, 1971/1921), Louis Thurstone's work on measuring attitude (Thurstone, 1928), and Milton Rokeach's efforts to understand attitude formation (Rokeach, 1973) serve as the foundations for this research field. These foundations, supported by developments in educational research, enabled focused research into a number of topics relating to attitudes in the years that followed. The work of Carl Hovland on the design of persuasive messages, along with the contributions of Edwards (1957), Osgood, Suci, and Tannenbaum (1957), and other researchers, spurred developments in the psychometrics of attitude assessment

(Shrigley & Koballa, 1992). Collectively, these efforts helped to shape attitude research to the point where it could offer testable treatments and measurable outcomes.

Attitudes Toward Science

Since the field was young, attitude researchers in science education have struggled to determine what is meant by "attitudes toward science." Before even attempting to establish such a definition, or delve deeper in a discussion about the contents of the attitude construct, some important distinctions are necessary. It is first important to outline the distinction, expressed by Klopfer (1971), between "attitudes toward science" and "scientific attitudes." The latter represent particular approaches for thinking about science[2] (Haladyna & Shaughnessy, 1982) or assessing ideas and information, and/or making decisions (Gardner, 1975). The label scientific attitudes, or scientific attributes as they are now more commonly referred to, stems from the notion that scientists possess or exercise a set of attributes, such as open-mindedness, that are considered desirable in students (Koballa & Glynn, 2007). John Dewey (1916), whose philosophy served as an early inspiration for attitude research in science, underscored the need for teaching scientific attitudes as an important aspect of educating reflective thinkers in the inaugural issue of the journal *General Science Quarterly*, which later became *Science Education* (Koballa & Glynn, 2007). Distinctly, attitudes toward science refer to an entirely unique construct. Furthermore, it is the latter attitudes that are the current focus of the presentation of literature herein. As a result of history, and the similarity in terminology between attitudes toward science and scientific attitudes, it is understandable how these terms might have been

[2] Some uses of "scientific attitudes" border more on philosophical positions or issues commonly associated with the nature of science. For example, Klopfer (1971) notes that these desirable attitudes include a commitment to evidence as the basis of belief, a belief in rational argument and a skepticism towards hypotheses and claims about the material world.

confused, conflated,[3] or even used interchangeably. In an effort to avoid further confusion, Germann (1988) reiterated the importance of distinguishing scientific attitudes from attitudes toward science and noted that these areas of research have diverged.

A second important distinction needs to be made about what the term “science” implies when considering students’ attitudes toward science.[4] Ramsden (1998) raises the issue that research into pupils' affective responses to science must be careful to distinguish between science *in school* and science *in general*. Ramsden elegantly articulates the need for this distinction:

> For most pupils, much of their formal experience of science is likely to come about through their science lessons at school, where they will engage in a variety of activities structured in such a way as to give them some appreciation of scientific concepts and methods of scientific enquiry. Outside school, pupils may also participate in a number of different activities or hobbies which could be [classified] as scientific. In addition, they will certainly receive a variety of other messages about science, not only from their experiences in science lessons, but from sources such as the media, books, friends and relatives. These messages will relate to who scientists are, what sorts of jobs they do, how they behave, and what effects scientific activity have on everyday life. Thus the overall picture pupils gain of science, and the ways in which they respond to it, will be influenced by their experiences in school and outside school. (p. 126-127)

Koballa and Glynn (2007) go on to explain “school science is typically the focus of investigations, but often this is not made clear” (p. 78). The concern, as highlighted by Lindahl (2007), is that students’ attitudes toward science in general can be quite different from their attitudes toward the science they experience at school. Speaking further to the need for careful distinction, Osborne, Driver, and Simon (1998) add that attitude researchers should consider the elements of school science, science in society, and scientific careers separately, defining each of them carefully.

[3] Klopfer (1971) did include scientific attitudes as an affective characteristic in science education. As precedent, Guilford (1967) previously described these attitudes as the “cognitive attitude” or a belief about thinking. Klopfer advocated that students should accept scientific inquiry as a way of thought and also adopt "scientific attitudes."

[4] The object of the distinction, science, is likely more complicated than initially presented – especially as it relates to students doing science. This will be discussed further in light of students’ divergent experiences, particularly as it relates to students in secondary school.

Attention to the Definition

With a groundwork now laid for discussing attitudes, this section will endeavor to explore how attitudes toward science have been conceptualized with an emphasis on what this means for future research. Since the early days concerns have been raised (Aiken & Aiken, 1969) over the absence of a clear definition of attitudes toward science. In a recent review of the literature, Osborne et al. (2003) contend "the concept of an attitude towards science is somewhat nebulous, often poorly articulated and not well understood" (p. 1049). Pearl (1974) adds to this conversation by claiming that many of the issues with measuring attitudes, including those outlined in the previous chapter and those that will be further communicated in this chapter, could be solved with an adequate definition. Koballa and Glynn (2007) make the case that adequate definitions are present in the research literature, directing readers to Ramsden (1998), Schibeci (1984), and Shrigley, Koballa and Simpson (1988). Given the availability of definitions in the literature, why, then, has attitudes toward science been so difficult to define?

To better understand the modern conceptions of attitudes toward science it is important to begin with attitudes. Bem (1970) explains that attitudes draw from preferences because they represent our "likes and dislikes" (p. 14). Koballa and Crawley (1985) connect attitudes to science by suggesting that attitudes toward science refer to whether a person likes or dislikes science, or has "a positive or negative feeling about science" (p. 223). Koballa (1988a) offers a more comprehensive explanation, stating that attitudes refer to our favorable or unfavorable feelings toward objects, persons, groups, or any other identifiable aspects of our environment. Blosser (1984) further specifies that "attitudes toward science" can be used to encompass scientific attitudes and interests, as well as attitudes toward scientists, scientific careers, methods of teaching science, science curriculum, or the subject of science in the classroom. Although

Blosser's definition is concise, it can be problematic for researchers because it encompasses so many possibly unique constructs and, as a consequence, lacks specificity.

The various definitions presented illustrate the various depths and meanings that can be attached to the construct of attitude. It is fair to say that the definition of attitudes toward science is nebulous, as Osborne, et al. (2003) contended, but this condition as Koballa and Glynn (2007) noted is not due to an absence of relevant literature. Instead, researchers (e.g., Blosser, 1984; Simpson & Troost, 1982) are largely to blame for the problem with a defining attitudes toward science as the have often failed to consistently set and explain their specific meaning in published works. The definition of attitude toward science adopted, as well as related theoretical frameworks, impacts the measurements employed or questions pursued by researchers. At this point we will break from the discussion of a definition in isolation. The following section will further the discussion by examining how the construct of attitudes toward science have been operationalized by researchers, drawing attention to the diversity of research topics that have spawned from these varying meanings.

Varied approaches to researching attitudes toward science. Researchers, at one time or another, have used attitudes toward science to describe: (a) attitudes towards science and scientists; (b) attitudes towards school science; (c) enjoyment of science learning experiences; (d) interests in science and science-related activities; and (e) intentions to pursue a career in science or science-related work (Tytler & Osborne, 2012). An earlier characterization of affective behaviors, originally by Krathwohl, Bloom and Masia (1964) that were included by Klopfer (1971) in a table of desired behaviors ensuing from science education, mirrors many of the topics listed above that have been addressed by researchers interested in students' attitudes toward science. These topics are expanded on below, drawing from the research literature and reviews of the field (e.g., Gardner, 1975, Haladyna & Shaughnessy, 1982, Osborne, et al., 2003), and include a brief summary of their current state.

Attitudes toward science and scientists. Klopfer (1971) groups the manifestation of favorable attitudes toward science and scientists, explaining that "if a student denounces science as a sinister enterprise or refers to scientists as 'eggheads' whom he prefers to ignore, he is hardly displaying favorable attitudes" (p. 577). The study of students' attitudes toward science and scientists was motivated by the apparent decline in the number of students electing courses and, subsequently, careers in science (Haladyna & Shaughnessy, 1982). Although research specifically into students' attitudes towards scientists seem to be less prevalent today, related investigations using measures such as the Draw a Scientist Test (e.g., Finson, 2002) remain commonplace. Also note that many measures for assessing students' attitudes toward science which are still in use (e.g., Test of Science Related Attitudes [Fraser, 1978]) continue to include items about the perception of scientists.

Declining trend in students' attitudes toward science. The reason to examine students' attitudes toward science is probably the same as always: "a desire to create the climate which best helps young people feel positive about . . . science" (Ramsden, 1998, p. 132). Regrettably, the research community generally agrees that students' attitudes toward science decrease as they move through formal schooling, with a steeper decline as students approach secondary school (Farenga & Joyce, 1998; Kelly, 1986; Pell & Jarvis, 2001; Speering & Rennie, 1996). Osborne et al. (2003) even draw attention to studies (e.g., Hadden & Johnstone, 1983) from the United Kingdom that show no improvement in students' attitudes from the age of 9 onwards, raising profound questions about the impact of school science on students' attitudes.

Gender and/or sex as a variable. Female students, compared to their male counterparts, reportedly experience a decline in their attitudes toward science earlier and at a more severe rate (Greenfield, 1997). In early elementary years, girls appear to both enjoy and participate in science classrooms just as much as, if not more than, their male counterparts (Pell & Jarvis, 2001). This discrepancy between boys' and girls' attitudes toward science widens as they move from elementary to secondary school (Kotte, 1992). Head (1985) explains that during adolescence individuals are attempting to establish their own identity and, as a consequence, are more strongly influenced by the normative expectations of peers. For boys, this may encourage them to *do* science, a subject often perceived as stereotypically male, and for girls this may lead them to *not do* science, as a means of establishing their gendered identity (Osborne et al., 2003). Early studies by Gardner (1975) and Schibeci (1984) reported that of all the variables that may influence attitudes toward science, sex generally had the most consistent influence. Historical concerns about gender equity in STEM-related fields are well documented (see National Academies, 2006). Arguing against the existence of innate differences, Baker and Leary (1995) claim that attitude measures have inaccurately portrayed gender differences and contend that attitudinal differences between boys and girls have been small in studies involving extensive interviews (e.g., Baker, Leary, and Trammell, 1992). Nonetheless, it is plausible that aspects of learning science (e.g., science focuses on the interests of boys) or their perceptions of science (e.g., science is a male domain [Keeves & Kotte, 1996]) negatively impacts females' attitudes and may detour them from related pursuits in the future.

Scientific interests. Klopfer (1971) argued that students should develop interests in science and science-related activities. Haladyna and Shaughnessy (1982) explain the nature of early studies in this area, noting the focus researchers placed on identifying the commonalities between the interests of students and scientists (e.g., Wynn & Bledsoe, 1967). This specific area, focusing on students' interests in relation to those possessed by scientists, is largely antiquated. Other studies involved behavioral checklists (e.g., Lewis & Potter, 1961) or interest inventories (e.g., Jones, Hua, & Rowe, 2000) in an attempt to measure science interest in students. The latter such inventories commonly contained a list of items, asking students to mark the activities which they found interesting. Renninger, Hidi and Krapp (1992) present student interest as a vital element of learning, often playing an important role in initiating, steering, and retaining student engagement in specific domains. However, interest inventories are generally restricted to their specific focus (e.g., environmental biology), yielding only a limited view of what may or may not be formative on attitudes to science (Osborne, et al., 2003).

Important to the present discussion, and to the larger discussion of attitudes toward science, is the term "interest," which as van Aalst (1985) points out, has been used with a range of different meanings, including curiosity, motivation and attitude. Ramsden (1998), summarizing Gardner (1985), explains that interest is distinct from motivation, but they are frequently related and Deci (1992) makes the case that understanding the impact of motivation on student learning requires a thorough understanding of interest. Authors (e.g., Hidi, 1990) often distinguish different kinds of interest, but individual interest is frequently coupled, or used interchangeably, with attitude. Individual, or personal, interest refers to a long-term preference for a particular topic or domain (Hidi, 1990). A key distinction between attitude and individual interest, highlighted by Krapp (2000), is that interest is always content specific and not a predisposition that applies across all activities. Therefore while you may have students with an individual interest in biology, this interest by no means implies that the student will be interested in other branches of science. By comparison, students' attitudes, especially as portrayed in recent publications, are more general and holistic with respect to their science-related experiences. Similar to attitudes toward science, student interest in science has been linked to later educational and career decisions (National Research Council, 1996), but, unfortunately, many recent publications (e.g., Lyons, 2006) also note a familiar decline in students' interest toward science as they progress through school.

Attitudes toward the subject of science. Klopfer (1971) noted that the manifestation of favorable attitudes towards the subject science is desirable in students. Though seemingly obvious, this goal is different in its intent compared to the more general goal of promoting attitudes toward science discussed previously. Research which falls into this category looks at students' attitudes toward science as a subject or topic in school (Haladyna & Shaughnessy, 1982). Osborne, et al. (2003) stress that the perceptions of school science, and the associated feelings about pursing future scientific studies, are likely to be the most significant in determining whether students will engage with science beyond what is required. The framework for the Next Generation Science Standards, for example, states, that "a rich science education has the potential to capture students' sense of wonder about the world and to spark their desire to continue learning about science throughout their lives" (Schweingruber, Keller, & Quinn, 2012, p. 28). One complication between students' perceptions of science and their attitudes toward school science is highlighted by the work of Ebenezer and Zoller (1993). The authors reported that 72% of the 1564 tenth-grade students surveyed thought science was valuable and 73% agreed learning science in school was important, but nearly 40% indicated that they found science classes boring.

Osborne and colleague's (2003) assertion about the importance of students' attitudes toward school science, notably distinct from science in general as previously discussed, carries meaningful implications for both the conception, and subsequent measurement, of student attitudes. To further deconstruct, students may make a distinction between learning science (e.g., listening to lectures and taking notes) and doing science (e.g., engaging in science-related activities, hands-on investigations, or inquiry-based lessons). Additionally, students may form preferences for, or make distinctions between, different branches of science[5] (e.g., biology vs. physics). A number of publications have assessed students' attitudes toward school and science (Morrell & Lederman, 1998), but some authors were quite general in their conception of school science (Germann, 1988). Moving forward, future research needs to be mindful of these potential distinctions and utilize measures with a broad array of items to all school science to be accurately characterized.

Relationship between attitude and achievement. Many researchers have investigated students' attitudes in the school setting for the purpose of uncovering their relationship to achievement. Numerous early studies highlighted the existence of a positive relationship between affective variables and precollege students' learning and achievement (Ainley, Hidi, & Berndorff, 2002; Hidi, 1990; Tobias, 1994) particularly in science (e.g., Chang & Cheng, 2008; Laukenmann, Bleicher, Fu, Gläser-Zikuda, Mayring, & von Rhöneck, 2003; Weinburgh, 1995). Fraser (1982) questioned the merit of this relationship, positing that improvements to students' attitudes would not necessarily improve achievement. Nonetheless, a meta-analysis of 43 studies, including 638,333 students from 21 countries with ages ranging from kindergarten through college, conducted by Willson (1983) revealed that the correlation between students' attitude toward science and their achievement was consistently significant (0.2-0.3) for students in sixth through tenth grades. In summary, Shrigley (1990), states that attitude and ability scores can be

[5] Note that even the common item that asks students to evaluate the statement "I enjoy science" might yield different responses depending on the kind of science class the student was enrolled in when asked.

expected to correlate moderately. Though seemingly weak, the strength of the relationship between attitude and achievement might be impacted by the narrow interpretation of attitude in many studies (Rennie & Punch, 1991), or the narrow definitions of achievement (Koballa & Glynn, 2007). Recent studies have continued to support a relationship between students' attitudes toward science and their achievement. Singh, Granville, & Dika (2002) concluded, based on analyses of the National Educational Longitudinal Study 1988 and subsequent investigation with 3227 eighth grade students, that students' attitudes toward science influenced achievement[6] by impacting the amount of time spent on science homework.

Attitudes toward science teaching and learning. This category includes research into student attitudes in terms of preferences, or enjoyment, from various aspects of the science learning experience (Klopfer, 1971). This sphere also encompasses research into students' attitudes toward particular methods of teaching science and content (Haladyna & Shaughnessy, 1982). Examples of such research includes investigations into instructional activities and methods (e.g., Fraser, 1980) and attitudes toward parts of the curriculum (e.g., Sullivan, 1979). Haladyna and Shaughnessy spoke of the potential of this area of research in their review of the literature. Focus on teacher pedagogy and aspects of learning experience is an understandable approach for examining trends, consistent with those discussed previously, suggesting students' enthusiasm for science declines with age (e.g., Piburn & Baker, 1993). Recent efforts closely related to students' preferences with the science learning experience have shifted[7] to attitude change interventions. Examples of such interventions include activity-based practical work (e.g., Thompson & Soyibo, 2002) and inquiry-based summer camps (Gibson & Chase, 2002). Some

[6] Singh, Granville, & Dika (2002) used student grades to represent achievement.
[7] The recent tendency to consider attitude change interventions is actually reminiscent of early work in the field by Robert Shrigley and others. Much of the research in the past 30 years has focused on assessing students' attitudes toward science and their correlates. Researchers interested in doing something about these attitudes have returned, or rather moved toward, intervention efforts.

programs have focused on particular groups (e.g., girls and minority students) to encourage their continuation in the science pipeline. Koballa and Glynn (2007) noted that these included after-school science programs and residential science camps as well as year-long science courses (e.g., Freedman, 2002; Haussler & Hoffmann, 2002; Jayaratne, Thomas, & Trautmann, 2003). Overall, Koballa and Glynn conclude that in many cases these interventions were complex and incorporated a number of activities in an effort to bolster students' attitudes toward science and reaffirm their commitment to study science. The results of these studies highlight successful interventions that engaged learners in hands-on science activities and reiterated the relevance of science through issue-based experiences (e.g., Haussler & Hoffmann, 2002; Siegel & Ranney, 2003).

Intentions to engage in science in the future. Klopfer (1971) states that a worthy part of the science learning experience is to encourage interested students to pursue science-related careers, though this should be expanded to include similar outcomes. Koballa and Glynn (2007) synthesized a number of recent studies that examined the influence of attitudes on students' decisions such as enrolling in elective science courses and pursuing careers in science. The authors highlight, among the factors found to influence students' science course-taking and career decisions (Robertson, 2000; Woolnough et al., 1997), the attractiveness of higher education courses and careers in science, the relevance of courses for future study and careers, self-confidence in science, and science interests are key contributors. Koballa and Glynn also draw attention to an earlier review, by Shrigley (1990), which concluded certain conditions are required for attitudes to be capable of predicting students' science-related decisions. The conditions stipulate:

1. The attitude and the decision must be measured at the same level of specificity.
2. Social context and individual differences, including cognitive ones, must be considered.

3. The person's intentions regarding the decision in question must be known.

These conditions, Koballa and Glynn note, were addressed in Butler's (1999) study. The purpose of this study was to identify the determinants of students' intentions to perform both laboratory and non-laboratory science learning tasks in grades 4 through 8. Butler concluded that students' attitudes toward the behavior, essentially their preferences about the specific behavior, were better predictors of their intentions. This was found to be the case for both types of tasks, laboratory or non-laboratory, and these attitudes toward specific behaviors were more predicative than students' attitudes toward science or their perceived social support for engaging in the behavior.[8] The only piece of information that is missing from Butler's study, which is unfortunately absent in many studies involving intention, is that the actual behavior of students was not reported.

Summary. The sheer number of categories which can be, or have at one time been, referred to under the umbrella term "attitudes toward science" speaks to the need for careful articulation and exemplifies why it is necessary for researchers to be very clear on their meaning of attitude toward science (Gardner, 1975). Previous reviews of the field (e.g., Haladyna & Shaughnessy, 1982; Schibeci, 1984) understandably lamented over the difficulties in trying to synthesize this body of research. From the overview of interrelated research areas presented, along with an introduction to some of the patterns (e.g., declining attitudes with age) and influential factors (e.g., gender) it is easy to see that a variety of research options are available. What this field epitomizes is that researchers must be thoughtful in selecting and defining their constructs to match their intended research questions. However, in a field with so many

[8] The measure social support for engaging in the behavior is commonly referred to as subjective norm in the research literature, a reference to Ajzen and Fishbein's (1980) model.

interrelated aspects this can be difficult to achieve. In an effort to inform the selections related to the present study, the concepts, patterns, and influential factors relevant to this field need to be investigated further.

Student Attitudes as Pieces to the Whole

In their comprehensive review of the field, Osborne et al. (2003) argue the first stumbling block for research into attitudes towards science is that attitudes do not consist of a single unitary construct, but rather consist of a large number of subconstructs all of which contribute in varying proportions towards an individual's attitudes towards science. The authors go on to establish the range of components used in prior studies (Breakwell & Beardsell, 1992; Brown, 1976; Crawley & Black, 1992; Gardner, 1975; Haladyna, Olsen, & Shaughnessy, 1982; Keys, 1987; Koballa, 1995; Oliver & Simpson, 1988; Ormerod & Duckworth, 1975; Piburn & Baker, 1993; Talton & Simpson 1985, 1986, 1987; Woolnough et al., 1994) to measure attitudes toward science. The list of components include: (a) the perception of the science teacher; (b) aspects of the classroom environment; (c) the value of science; (d) self-esteem in science; (e) attitudes of parents towards science; (f) attitudes of peers and friends towards science; (g) enjoyment of science; (h) motivation towards science; (i) achievement in science; (j) anxiety toward science; and (k) fear of failure in a science course. Some of the components listed above have already been elaborated upon in the earlier discussion about historical definitions (Osborne et al., 2003) and characterizations (Klopfer, 1971) of attitudes toward science. The most essential of the remaining components, as they recount the history of the field and inform on the present study, are presented in greater detail in the sections that follow.

The science teacher and classroom environment. Researchers have emphasized the influences of the science teacher as well as learning environment on students' attitudes toward science (Haladyna & Shaughnessy, 1982; Wright & Hounshell, 1981). The capacity for teachers to influence students has been shown to relate to quality variables, such as the academic preparation of the teacher in the specific field of science, and teaching practices (Ebenezer & Zoller, 1993). General teacher practices have been highlighted, including use of feedback, expectations set, and level of encouragement offered, as contributors to students' attitude, motivation, confidence, perception of competence and ability, as well as science career motivation (Chouinard, Karsenti, & Roy, 2007; George, 2000; Stake & Mares, 2001). More specific to the teaching and learning of science in the classroom, studies have uncovered positive relationships between student experiences and their attitude toward science (Hall & Sandler, 1982; Papanastasiou, 2002; Simpson & Oliver, 1990). For example, teachers who facilitate inquiry-based learning may contribute to a number of desirable outcomes, including the promotion of positive attitudes toward science. Studies with middle and high school students show that inquiry-based science activities have positive effects on students' science achievement, cognitive development, laboratory skills, science process skills, and understanding of science knowledge when compared to students taught using a traditional approach (Chang & Mao, 1998; Ertepinar & Geban, 1996; Geban, Askar, & Ozkan, 1992; Mattheis & Nakayama, 1988; Padilla, Okey, & Garrand, 1984; Purser & Renner, 1983; Saunders & Shepardson, 1987; Schneider & Renner, 1980; Wollman & Lawson, 1978). Additionally, studies have suggested that students who are presented with an inquiry approach have improved attitudes towards both science and school while other studies show more negative attitudes surfacing from traditional methods (Gibson, 1998; Jaus, 1977; Shrigley, 1990). Engaging students and allowing them to do science provides a greater intellectual challenge than the numerous mundane activities (memorizing, recall and copying) that pervade the contemporary science curriculum (Osborne & Collins, 2000).

Perceived utility of science. There is a body of research (e.g., Hasan, 1985) which draws attention to the connection between students' perceived utility of science and their attitudes toward science. George (2006) found in a cross-domain examination of students' attitudes toward science and their perceived utility of science that the overall trend was positive over a 5-year longitudinal study. Adding to the previously noted gender effect, Catsambis (1995) concluded that males, more than females in a sample of eighth grade students, possessed the attitude that science would be useful in their future. This finding is consistent with more recent work, but evidence suggests that students perceive the usefulness of science differently depending on the science courses to which they are exposed. For example, DeBacker and Nelson (2000) distributed 242 qualitative questionnaires to high school students in grades 10-12 who were enrolled in biology, accelerated chemistry, physics, or advanced placement physics. The authors note, for their sample, that girls had higher scores on perceived instrumentality in biological sciences. Based on their findings, DeBacker and Nelson argue that students who choose to continue to study science beyond the required number of classes are those who perceive connections between science and their future goals.

Science self-concept. Science identity encompasses who students are, what they believe they are capable of, and what they want to do and become in regard to science (Brickhouse, 2001). The notion of a science identity, or a self-science concept, can be found in early discussions pertaining to students' attitudes toward science. Gardner (1975) noted that students' self-concept relates to their attitude toward science. Shrigley, Koballa, and Simpson (1988) discussed the inclusion of "self-perception" as a component in their conception of attitude.

Tytler, Osborne, Williams, Tytler, Clark, Tomei et al. (2008) identified a strong connection between interest, identity, and self-efficacy in framing students' response to science. The identity construct appears to play an integral role in students' perception of science and their likelihood of selecting to pursue a science-related career.

Like the other aspects of student attitudes discussed here, the importance of the science self-concept has been reported as more specific for certain groups. Hasan (1985) claimed that perception of science ability is especially critical for students at the secondary level and has a profound effect on their attitude toward science. In addition, similar to previously discussed trends, Simpson and Oliver (1990) found that out of a sample of 4,500 students, males had consistently higher scores relating to science self-concept and attitude toward science. Possibly related in light of the documented gender gap in the science (e.g., National Academies, 2006), Mayberry (1998) posited that female students' self-concept, or science identity, has profound influence on their decision to pursue science. Many researchers examining science self-concept in students place a particular emphasis on sex and gender, with a growing tendency to look outside science education research literature and toward feminist paradigms in search of explanations that transcend the deficit perspective (Baker & Leary, 1995).

Roles of family and peers. For the adolescent student, in many cases, the family or home environment exerts a strong influence on their attitudes toward science. Studies have shown that the attitudes of the family toward science (Talton & Simpson, 1987), specifically the attitudes of the mother (Schibeci, 1989), contribute to students' attitudes toward science. Evidence indicates that family plays a formative role in developing students' attitudes, encouraging students' interest and supporting students' decision to pursue science coursework and careers. Some studies have found that parental effects differ by race/ethnicity for science achievement, attitude, and interest (Andre, Whigham, Chambers, & Hendrickson, 1999; Ferry, Fouad, & Smith, 2000; Gilmartin et al., 2006; Huang, Taddese, & Walter, 2000). Kremer and Walberg (1981) analyzed thirteen studies that incorporated home environment variables in relation to student learning outcomes. The authors, consistent with other studies (e.g., George, 2000; George & Kaplan, 1998; Keeves, 1975), concluded that a high degree of parent involvement related to heightened attitudes toward science and increased interest in science among adolescents. George and Kaplan's (1998) examination of parental involvement found that students' attitude scores were higher when parents were involved in their experiences, such as by visiting libraries and museums, and partaking in science activities. Schibeci and Riley (1983) go on to suggest that parent education, in addition to home environment, exerts a strong influence on both students' attitude and achievement.

Peer relationships, like familial ones, have been suggested to play a similar formative role in the attitudes and interests of pre-college students. Research has found peer attitude and interest in science to be a predictor of student attitude and enjoyment of science (Fraser & Kahle, 2007; George, 2000; Simpson & Oliver, 1990). Shrigley (1983) noted that this influence of peers on students' attitude toward science is most pervasive among adolescents with Simpson and Oliver (1985) adding that that the relationship increased from age 11 onwards and peaks at age 14 as students feel the influence of group norms. Nonetheless, Crawley and Coe (1990), Koballa (1988b) and Oliver and Simpson (1988) have all found that social support from peers contribute to students' decisions to pursue additional science courses. In addition, students with peers that share their science-related interests enhances their perception of themselves as future scientists (Stake & Nikens, 2005).

Unattractive qualities of science. As research into students' attitudes toward science have paid special attention to students' selection of science courses, researchers have made a point to investigate the qualities of science courses that might detour students. An example of such a quality, documented in the research literature, is a belief held by students that science is a "hard" subject (Millar, 1991). Millar lists four reasons (p. 68), which he posits are the consequence of certain unavoidable characteristics of science and/or of learners, why science has acquired a reputation for being hard to learn. In summary, one or more of the following may contribute to students' disinterest in science and unwillingness to pursue additional studies:

1. Science is abstract.
2. More than simply the accretion of knowledge, learning science involves reconstructions of meaning.
3. Learners may be confused or alienated by certain aspects of the nature of science.
4. Learners may not see any "pay off" for the effort required to learn science.

Osborne et al. (2003) portray students' experience with science as falling victim to issues with teaching practices and set curriculum. The authors draw attention to tendency for students to be required to memorize obscure material, learn about antiquated processes and technology, and be bombarded with intangible theories and phenomena. To further illustrate that school science can be quite discouraging, consider the struggle and frustration with achieving good grades that Diana (white, female) describes:

> I was very like frustrated . . . I had a ton of homework, and I wouldn't go to sleep until like one [o'clock] . . . And I just was really struggling. I was fighting to keep my grade as a 'B.' Honestly, like my whole school life I've gone through science pretty easily, and this year was the first year that I actually needed to put extra effort into it and work hard for it. And still, I'm working for a 'B!' You know, usually, I'm working for an 'A' . . . And the pressure of the AP exam, I hated that. (Aschbacher, Li, & Roth, 2010, p. 571)

Aschbacher et al. followed an ethnically and economically diverse sample of 33 high school students to explore why some who were once very interested in pursuing science-related majors or careers had changed their minds while others persisted. Diana's testimony is likely similar to many other students' experiences with science. She goes on to describe how this crucial experience negatively impacted her attitude toward science:

> Diana: Last year [chemistry] I understood everything. This year, like, at a few points during the day, I would just think, "Is this lady speaking the same language that I speak?! Some of these words are just clueless." And I couldn't get over how people just automatically understood 'em, like they were born with the biology gift in their brain or something . . . I felt like, "Wow, I do not belong here."
>
> Interviewer: Did that sort of make you like science less?
>
> Diana: Yeah. Because I . . . this sounds really bad. I like things that I'm good at, I guess. Because I see no point to working hard if you know that other people have an upper hand over you. So, like they have, they have a certain benefit over you. So, I just don't bother. I'd rather stick to what I like doing.

Between these two segments that Aschbacher et al. captured, it is clear that Diana had reached a point in her program of education where science seemed particularly abstract to her and difficult to learn. Despite once aiming to pursue a career in a science-related field, Diana has lost sight of the payoff for learning science that Millar (1991) mentioned and abandoned her ambition.

Achievement motivation. In addition to being difficult, many science students, especially adolescents, view science as a boring subject that fails to motivate them (Rennie, Goodrum, & Hackling, 2001). Motivation to do science, or rather the motivation to do well in science, is mentioned here because it is thought to explain some discordant findings in the research literature. Recall that research (e.g., Kotte, 1992) generally supports a gender effect whereby male students report more positive attitudes than females. In an initial study of gender and students' science interests, Kahle examined data from the National Assessment of Educational Progress (NAEP) and found that female students described their science classes as “facts to memorize,” and “boring” (Kahle & Lakes, 1983). In contrast, Catsambis (1995) found that males were more likely to look forward to science class. In spite of differences in attitude and interest, studies (e.g., Catsambis, 1995) continue to show that girls are able to perform as well, or even better, than boys in science. One possible explanation for this, offered by Simpson and Oliver (1985), is that female students may be more highly motivated to achieve in science. Subsequent work by Simpson and Oliver (1990), involving responses from approximately 4,500 students, revealed that females had consistently higher scores, compared to males, regarding their achievement motivation. Oliver and Simpson (1988) claim a strong relationship exists between students’ attitude towards science, motivation to achieve and their self-concept about their ability to achieve in science. This claim, in light of the evidence presented here, speaks to the potential for students’ attitudes toward science, which may be influenced by negative experiences or perceived qualms, to be overridden by other more closely held convictions.

Summary. A large body of evidence suggests that affective variables are interrelated (Finson, 2002; Fung, 2002; Häussler & Hoffmann, 2000; Schibeci & Riley, 1986; Siegel & Ranney, 2003) with interactions between students’ attitudes, interests and self-efficacy (Boylan, Hill, Wallace, & Wheeler, 1992; Dimopoulos & Smyrnaiou, 2005; Finson, 2002; Fung, 2002) affecting achievement (Britner & Pajares, 2006; Häussler & Hoffmann, 2000; Schibeci & Riley, 1986; Siegel & Ranney, 2003), decisions about future studies, career choices, personal and social lives (Britner, 2008; Dawson, 2000; Schibeci & Lee, 2003; Song & Kim, 1999). Within this intricate web of relationships are key factors (e.g., home environment) which are formative of students’ attitudes. Research also highlights other features (e.g., unattractive qualities of science) that might dissuade students from science-related careers and internal variables (e.g., achievement motivation) that might be able to compensate for low attitudes toward science. To make sense of this complexity it would be desirable to promote continued empirical research into specific relationships involving affective variables (e.g., attitudes and perceived utility of science). However, the sheer complexity of these interactions complicates this task. Instead, it might be more fruitful to focus on identifying key interactions and to operate within a conceptual framework to better organize empirical efforts.

Conceptual Frameworks for Research into Students' Attitudes toward Science

Early frameworks. In the late 1960s science education researcher Robert Shrigley came across some literature in social psychology pertaining to attitudes. Shrigley, at this time, was planning to test specific treatment effects on sixth-grade science students, assessing the impact on their attitudes, and the literature he happened upon detailed how to design, test, and revise theoretical models that served to direct the analysis, modification, and measurement of attitudes (Shrigley & Koballa, 1992). Carl Hovland's learning theory focused on attitude change, framing it as a persuasive task involving a communicator, message, audience, and mode of delivery. Hovland, Janis and Kelley (1953) encouraged researchers to investigate the effect of information on attitude change, the characteristics of the information source and the audience. Shrigley and others introduced Hovland's learning theory to the field of science education by launching investigations into specific treatment effects using the stimulus-response approach (see Shrigley, 1976, 1978). These researchers also advanced the use of Likert scales in the field of science education to measure attitudes, a mode of assessment which continues to dominate the field today.

Over time, in the face of diminishing treatment effects and theoretical concerns with Hovland’s model, especially with regard to explanatory power, researchers started to explore other options. Committed researchers, such as Petty and Capcioppo with their work on the elaboration likelihood model (Petty & Cacioppo, 1986), attempted to alleviate the shortcomings of the Hovland model. Ultimately, however, the ambitions and needs of the field changed. One of the major failings of the Hovland model, raised by researchers investigating student attitudes in science education (see Shrigley, 1990), was its ineffectiveness in relating attitudes with future behavior. In an attempt to understand why students were shying away from science, the field shifted to a more robust model that incorporated a greater range of variables causally related with behavior that could still facilitate attitude change research (Shrigley & Koballa, 1992). Science education researchers seeking a more adequate theory to explain student attitudes again turned to frameworks rooted in social psychology.

A paradigm shift impacting attitude research. The 1990s marked a time of great transition for researchers involved with attitude research in science education. Major works emerging from this period, Baars (1986) recounts, were influenced by developments in psychology and led to a redefinition of the attitude construct. Research paradigms in social and educational psychology that had long influenced the study of students' attitudes toward science shifted from behaviorism to a more cognitive orientation (Richardson, 1996). This change in theoretical perspective, Koballa and Glynn (2007) explain, divided attitude from cognition. Attitudes, now aligned with affect, were consequently less of a concern to researchers, instead replaced by the construct of beliefs which were thought to explain the actions, or behaviors, of learners. In the wake of distressing reports of students' disinterest in studying science (e.g., United States Department of Labor, 2007) and pursuing science-related careers (e.g., Schreiner & Sjøberg, 2004), investigators have again been attracted to research students' attitudes toward science with the underlying hypothesis that attitudes help to steer school performance and career choice (e.g., Wyer, 2003).

As a result of the aforementioned transition in the field, definitions of attitudes toward science became intimately connected with behavior. Koballa (1988a) asserts the ultimate aim of measuring students' attitudes toward science is to predict their future behavior. Ramsden (1998) revisits Shaw and Wright's (1968) definition of attitude, highlighting the inclusion of a behavioral component:

> Attitude is best viewed as a set of affective reactions towards the attitude object, derived from concepts of beliefs that the individual has concerning the object, and predisposing the individual to behave in a certain manner towards the object. (p. 13)

In later years, Icek Ajzen and Martin Fishbein would help to better situate the attitude construct by clarifying the somewhat ambiguous causal chain that Shaw and Wright alluded to in their definition. Instead, Fishbein and Ajzen (1975) described attitude as a learned predisposition to respond in a consistently favorable or unfavorable manner toward a person, place, thing or event (i.e., the attitude object). Compartmentalizing attitude, for Ajzen and Fishbein, was necessary in order to make the transition from definition to theory as will become apparent in the next section. Still, researchers who have continued to focus heavily on attitudes have amalgamated past definitions with modern perspectives that reflect the contributions of Ajzen and Fishbein. This is well illustrated by Oppenheim (1992) who offers the following:

> Attitudes . . . [are] . . . a state of readiness or predisposition to respond in a certain manner when confronted with certain stimuli . . . attitudes are reinforced by beliefs (cognitive component), often attract string feelings (emotional component) which may lead to particular behavioral intents (action-tendency component). (p. 74-75)

The three related definitions presented above highlight changing perspective of researchers in the field following the cognitive revolution of the 1990s. By championing student behavior as the outcome variable, and compartmentalizing attitude as a contributing factor, the discussion now turns to how these factors are related and what other factors are involved.

Theories of reasoned action and planned behavior. Researchers and educators were attracted to the work of Ajzen and Fishbein who claimed that affective, cognitive, and behavioral aspects of attitude interact in a causal and unidirectional manner (Figure 1). The theory of reasoned action, proposed by Fishbein and Ajzen (1975), offers a unifying and systematic conceptual framework, which can be used to explore a range of human behaviors. The theory was "born largely out of frustration with traditional attitude–behavior research, much of which found weak correlations between attitude measures and performance of volitional behaviors" (Hale, Householder, & Greene, 2002, p. 259). Butler (1999) concluded that the theory of reasoned action was a natural fit in science education because many of the desired student outcomes, such as deciding to take a high level science course or pursuing a science-related career, represented specific behaviors.

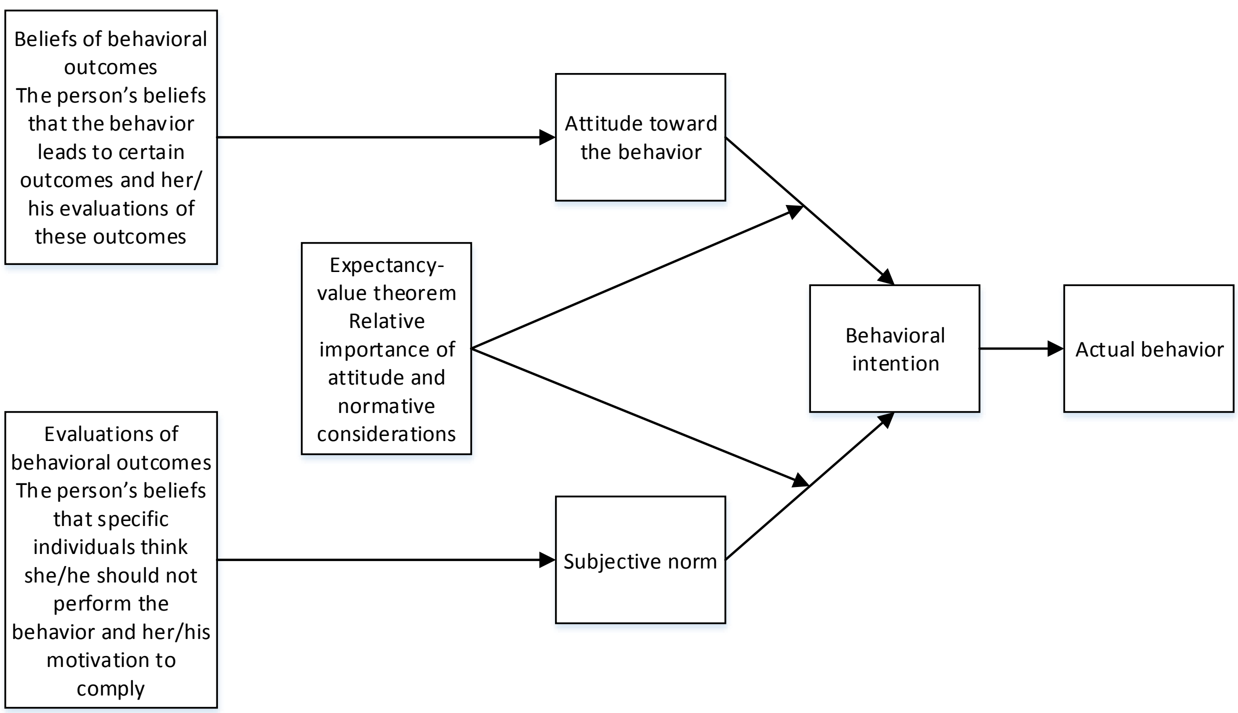

Figure 1. Factors determining a person's behavior. Arrows indicate the direction of influence (Source: Adapted from Ajzen & Fishbein, 1980).

According to the theory of reasoned action, a person's intention to perform a given behavior, rather than their attitude toward the behavior, is more closely linked to the actual behavioral performance (Fishbein & Ajzen, 1975). For that reason this theory focuses on the distinction between attitudes towards some "object" (e.g., person, place, thing, or event) and attitudes towards some specific action to be performed on that "object" (Osborne, et al., 2003). To clarify, students' attitudes towards doing science is thought to be more predictive of their behavior than their overall attitudes towards science. Shrigley et al. (1988) suggested, in their review of the literature, that this relationship became apparent from inconsistencies among early studies between reported attitudes and subsequent behaviors. Osborne et al. add to this by articulating that preferences, resulting from attitudes, will not necessarily be related to the behaviors a student ultimately exhibits.

> [B]ehavior may be influenced by the fact that attitudes other than the ones under consideration may be more strongly held; motivation to behave in another way may be stronger than the motivation associated with the expressed attitude; or, alternatively, the anticipated consequences of a specific behavior may modify that behavior so that it is inconsistent with the attitude held. (Osborne, et al., 2003, p. 1054)

As an example, consider that a student may have a positive attitude toward science, but that student may avoid publicly demonstrating that preference around their peers who he/she perceives might look down on them for that preference. In this case it is likely the student holds a positive attitude, but he/she might be quite reluctant to engage in certain science-related endeavors for fear of being judged or shunned by their friends. Even if the student in this example did not have a positive attitude, he or she might be compelled to perform the behavior in question if they had a high motivation to comply (e.g., the behavior was important for future success) or perceived some greater advantage could result from their engagement (e.g., the behavior improves the likelihood of winning a scholarship). In review, the theory suggests an individual's behavior is determined by their intention, and intention is a joint product of attitude towards the behavior and the subjective norm (i.e., beliefs about how other people would regard their performance of the behavior). The relative importance of the individual's attitude toward performing the behavior, including outcome evaluations, and their personal beliefs, which include their normative beliefs, are weighed in the expectancy-value theorem.[9] To put it simply, the more favorable the attitude and the subjective norm, and the greater the perceived control, the stronger the person's intention is to perform the behavior in question.

Assumptions and concerns. The theory of reasoned action is rooted in two significant underlying assumptions that need to be thoughtfully examined. The first assumption, as identified by Crawley and Koballa (1994), is that actions that relate to behavioral intention do not require special skills or abilities, unique opportunities or the assistance of others, and "require only that the individual possess the motivation to perform the behaviors" (p. 38). However, it is possible that this assumption may prove invalid when dealing with students thinking about their future science studies, especially in relation to their real or perceived abilities to succeed in college science. The second assumption is that humans are rational, in control of their behavior, and make well-informed decisions. The theory of planned behavior, was incorporated as a means of shoring up the absolute dichotomy resulting from the premise that individuals are either in complete control or have no control over their behavior. In reality, this assumption might not be applicable to the situation of younger students contemplating and/or making decisions about their immediate or long-term educational goals, such as enrolling in additional science courses in high school or pursuing a college science major some years in their distant future. Despite these criticisms and issues associated with underlying assumptions, it

[9] Some studies that have employed the TRABP in science education research (e.g., Crawley & Black, 1992) have employed the model in a more scripted manner, using each component of the model as weighted variables in an equation, to explore factors that influence students' decisions to perform a specific behavior of interest.

is unclear whether previously articulated concerns (e.g., Liska, 1984) have been fully remedied. Therefore, it is plausible that not all of the aforementioned assumptions apply in the case of precollege students where families may have significant say in their children's academic decisions and other life choices.

In an effort to address concerns of limited applicability (see Liska, 1984), Ajzen (1985) extended the theory of reasoned action by introducing the theory of planned behavior. This extension takes into consideration that internal factors, such as a person's skills or ability, as well as external factors, like the co-operation of others or lack of resources, may influence an individual's behavior. Another notable contribution of this theory is that it introduces the concept of perceived behavioral control, acknowledging that a person may believe they do not have full control over their own behavior. As a result, this theory introduces more variables which can influence students' intention to perform a given behavior independent of their attitude toward that behavior (Crawley & Koballa, 1994). Overall, Ajzen's theory of planned behavior offers a framework to predict and understand science-related behaviors and allows for the construction of instruments to measure the variables guide science-related behavior. Convergent findings from Crawley and Coe (1990), Koballa (1988b) and Oliver and Simpson (1988), concluding that support from peers and a positive attitude towards enrolling in a course are strong determinants of student choice to pursue science courses voluntarily, suggest that the theory has at least some partial validity. Some researchers question aspects of this model, perhaps rightfully so considering the limited number of empirical investigations published in the literature, but it has a committed following and work has been conducted in recent years to further develop the model (e.g., Crawley & Koballa, 1994). At the present, however, it remains at the forefront of competing models for shaping attitude research in science education (Osborne, et al., 2003).

Use of the TRAPB in science education research. The majority of science education researchers employing TRAPB (e.g., Crawley & Black, 1992; Crawley & Coe, 1990; Crawley & Koballa, 1992) have attempted to understand students' decisions to engage with science by focusing on factors that are believed to contribute to their intention to pursue elective courses in science. This is illustrated by early research efforts with the TRAPB that attempted to gauge students' intentions based on the relative strength of the determinants. Koballa (1988b) examined eighth-grade female students' intentions to enroll in at least one elective high school physical science course. Using multiple regression analyses on behavioral intention, Koballa concluded that attitude toward the behavior carried more weight than subjective norm. Crawley and Coe (1990) furthered this line of research by exploring whether eighth-grade students would take science in ninth grade if it were considered an elective course. As a result of this study the authors concluded that the relative contributions of attitude and subjective norm components to the prediction of intention to enroll in a science course in ninth grade vary depending on students' ability and individual characteristics (i.e., gender and ethnicity). Crawley and Koballa (1992) expanded on this avenue of research by examining determinants that influenced a sample of tenth-grade students' decision to enroll in an elective high school chemistry course. In this study a sub-sample of students were asked to list the advantages and disadvantages of enrolling in chemistry, persons who would disapprove of chemistry enrollment, and factors that facilitate or inhibit enrolling in chemistry. These tasks, respectively, represent behavioral, normative, and control beliefs, which are key components of the TRAPB model. Following analysis, student responses collected were used as an empirical basis for the Chemistry Interest Questionnaire, which was then administered to the sample.

To summarize, the above review illustrates that the majority of extant studies in this domain have focused on the determinants that contribute to students' behavioral intentions regarding the pursuit of science, in the specific sense of electing to take one or more science courses in the near future. As a result, the assessment of student attitudes was a means to address the elements of the TRAPB model so that the associated intentions could be identified. However, this approach raises questions regarding the applicability and accuracy of the model in terms of using attitudes as predictive of behavioral intentions, as well as the importance of context.

Other notable frameworks. The TRAPB model inspired by the work of Ajzen and Fishbein is at the forefront of models used to examine and interpret students' preferences and behaviors in science education research (Osborne et al., 2003; Nieswandt, 2005). Unsurprisingly, however, several other models have been proposed throughout the long history of attitude research. While many of these theories and models have been discarded, some attempted to encompass novel ideas and others continue to garner support. In this section a small sample of these notable frameworks will be presented.

Influences and factors leading to involvement in science. Simpson and Oliver (1990) disclose that they set out to synthesize a model (or models) that would depict precise mathematical relationships along with important qualitative dimensions. From data collected in a 10-year longitudinal study initiated in 1979, examination of the major components uncovered from the study indicated no parsimonious mathematical formula was likely to emerge. The authors instead offered an illustration (Figure 2) to depict how they proposed the most important variables in this study to relate spatially and temporarily in terms of major influences and decision-making factors leading to involvement in science. The model includes four major life phases which coincide with four major decision-making stages.

Many of the phases and relationships included in Simpson and Oliver's model were suggested, from data collected, but have not been substantially investigated further. Simpson and Oliver's model is notable because it allows the major influences on engagement to change as students get older. One possible problem with the TRAPB is that students, especially young

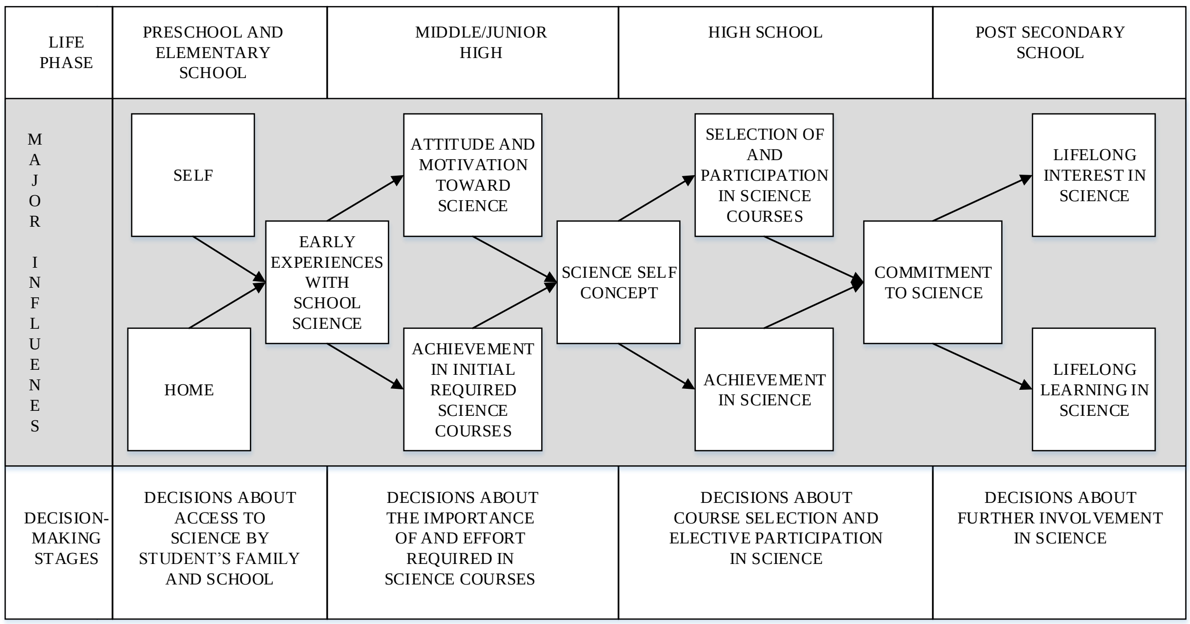

Figure 2. Simpson and Oliver's model of major influences and decision-making factors leading to lifelong involvement in science (adapted from Simpson & Oliver, 1990).

students, only think about their future science involvement in a limited sense. For example, a student might not be thinking about whether or not they will take elective science courses in high school when they are in eighth grade. However, it would be more plausible to believe a 10th-grade student has given the matter some consideration. In Crawley and Black's (1992) study of 8-11th grade students' intentions to take physics using the TRAPB model, the authors noted warm period, the early years of secondary school in this case, where students formed beliefs about the consequences of enrolling in physics. Student responses for this age range indicated they had thought positively about pursuing advanced science courses and related careers, but had not yet fallen prey to the less favorable attitudes typically associated with older students. Mindful of this formative period, the authors recommended that efforts should be made to reinforce the importance of advanced study in science and introduce science-related careers during this time.

Aside from the fluidity afforded to the determinants of student engagement, the Simpson and Oliver (1990) model raises some conceptual questions and ultimately appears empirically weaker than the TRAPB model. Conceptually, from previous discussion, it is clear that many of the influences included in the model are interrelated. Moreover, looking at other studies in some cases it appears that the authors are omitting important connections in the model. The connection between students' attitude toward science and their achievement in science, for example, has been aptly highlighted (e.g., Chang & Cheng, 2008). The authors depict self-concept as a mediator between attitude and achievement. However, it seems unlikely that foundational influences, such as self (e.g., gender and ethnicity) and home (i.e., culture), lose their influence over time and no longer contribute to this concept. To confirm such relationships, in this or any model, it is important to examine them specifically. Beyond concerns relating to the connectedness of influencing factors, the Simpson and Oliver model does not help dissect the reasons students might avoid science.

Framework for studying attitudes toward the school science. Haladyna and Shaughnessy's (1982) framework for studying students' attitude toward the subject of science places more emphasis, compared to conceptualizations of the TRAPB, on how the schooling process shapes students' attitudes toward science. The authors posit three independent constructs, the teacher, student, and learning environment, and consider variables both internal (e.g., curriculum, administration) and external (e.g., culture, gender) to the schooling system (Figure 3). Haladyna and Shaughnessy contend the preferences and characteristics of the teacher (e.g., attitudes, training, and practices), in particular, play a very influential role in shaping students' attitudes toward science. This approach is certainly plausible considering that this circumstance would encompass a number of important people (e.g., science teacher and peers) that are known to impact students' attitudes toward science.

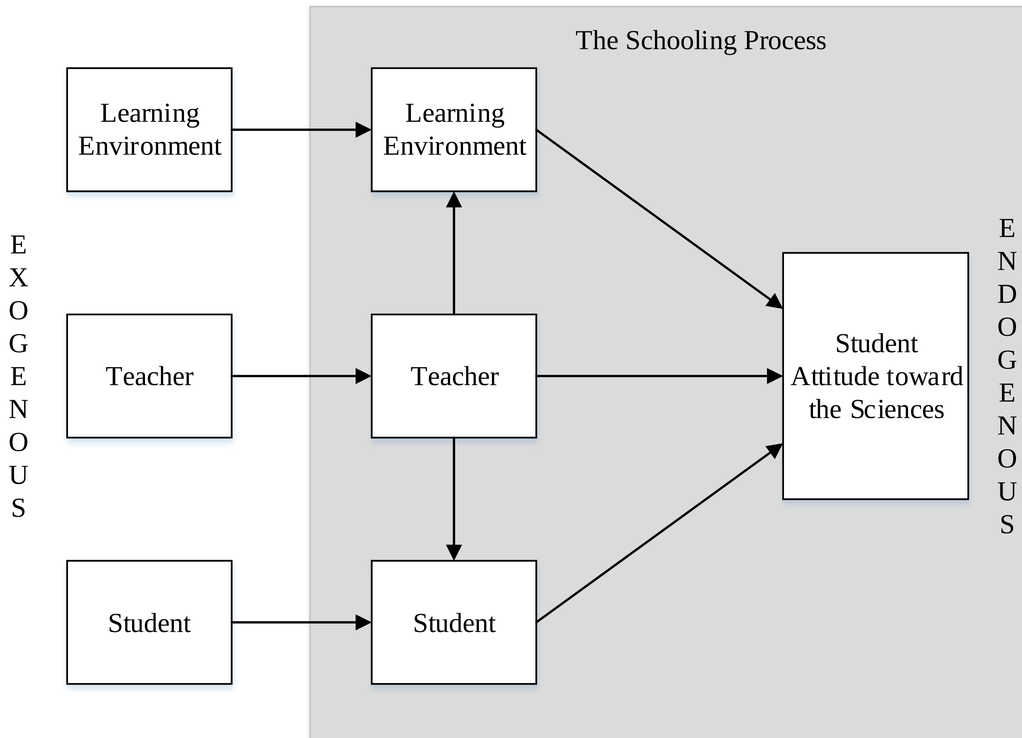

Figure 3. Framework for Studying Attitude toward the Subject of Science (Source: Adapted from Haladyna & Shaughnessy, 1982, p. 550).

A contingency of researchers in the field of science education are attracted to models like the one proposed by Haladyna and Shaughnessy (1982) because they portray the schooling system as being fluid and dynamic, instead of highly compartmentalized. Nieswandt (2005) questions the viability of highly compartmentalized models, namely the model derived from the theory of planned behavior, due to inconclusive empirical evidence showing how one or two variables can be altered and result in an observable change in student behavior. Haladyna and Shaughnessy, in stark contrast to the theories of Ajzen and Fishbein, do not include behavior in their model. However, at the present, a concern with this model, or models like it, is the apparently limited level of testability, and the consequence of appearing less robust, compared to the theory of planned behavior. Haladyna and Shaughnessy's framework might be appropriate for considering attitude change interventions, but it is only useful to the larger aim of encouraging students to study science and pursue science-related careers if attitude is really the chief determinant of these decisions, profoundly influenced by school science that is not adequately accounted for in other models. The majority of researchers agree that student attitudes are important, but they situate them as a piece in a larger construct. Interestingly, however, the science teacher and classroom environment are often cited as important influences on students in the literature though their suggested contribution is less apparent in current models (i.e., the TRAPB).

Frameworks incorporating identity. There is a growing body of work relating students' attitudes toward science that is grounded in theoretical construct of "identity," which provides an analytic lens for the construction of explanatory hypotheses for students' choices (Osborne Simon, & Tytler, 2009). Several notions of identity are discussed in the research literature. Two of the more detailed examples of how science identity has been conceptualized by researchers are presented here, followed by a broader summary of the place of such frameworks in the field. The first example, drawing from the work of Etienne Wenger-Trayner (Lave & Wenger, 1991; Wenger, 1998), explains learning as taking place through everyday social interactions within "communities of practice," such as those found at school, home, or work. These situated learning experiences, whereby participants interact and learn together, shape an individual's identity. Within a situated learning framework, Aschbacher, Li, and Roth (2010) discuss how students' science identity is informed by their lived experiences and social interactions at home, in school, and in the larger world. It is based on how students view themselves and believe others view them as they participate in science-related endeavors. The authors note that students' science identity likely changes and evolves over time as they are likely to participate in multiple social communities where they must negotiate their identities back and forth along the rules and values set up by these communities (Furman & Calabrese-Barton, 2006; Lave & Wenger, 1991).

The second example, while similar to the previous, focuses more on the individual's perception of culture. For most students the transition from a student's life-world (e.g., peers, family, culture, etc.) into a science classroom is a cross-cultural experience. These transitions can be treated as cultural border crossings (Aikenhead, 1996, 1997). Aikenhead (2005) argues that for many students coming to appreciate science requires an identity shift whereby students come to consider themselves as science-friendly. This identity shift is complicated by the reality that science learning can cause conflict on a personal level. Costa (1995), using empirical data from a diverse population of high school science students, categorized students according to their ease of transitions between external cultures into the culture of the science classroom. In summary, for students these transitions are *smooth* when the cultures of family and science are congruent, transitions are *manageable* whenever the cultures are somewhat different, transitions tend to be *hazardous* when the cultures are diverse, and transitions are virtually *impossible* when the cultures are highly discordant (Aikenhead & Jegede, 1999). Relevant to the present discussion, Aikenhead and Jegede comment that students might avoid school science to sustain their self-worth whenever they experience the foreign culture of school science.

Nieswandt (2005) highlights that the role of internal factors (e.g., confidence), as well as several external factors (e.g., resources, co-operation of others), have been sorely overlooked In the large body of research rooted in Fishbein and Ajzen's theories of reasoned action and planned behavior. Nieswandt makes the case that these omissions are very relevant to science learning, especially with regard to students' self-concept, self-efficacy, and motivation. It is important to explain that past research efforts did acknowledge students' identity, or self-concept (Gardner, 1975), as profound influences on their attitudes toward science and their decisions to pursue science-related careers (Mayberry, 1998). Researchers worked to incorporate identity into attitude frameworks and investigated identity along with known correlates of attitude. Shrigley et al. (1988), for example, advocated the inclusion of "self-perception"[10] as a component of the attitude construct. Also notably, Bloom (1976) predicted that an attitude complex, including affective variables and subject-related self-concept, would account for up to 25% of variability in students' achievement scores. Despite this past acknowledgement of internal factors, Nieswandt's remark about their absence in the dominant research of the field is telling.

Researchers have approached internal factors, including identity among others, both qualitatively and quantitatively in order to gauge their contributions to students' attitudes toward science. For example, Speering and Rennie (1996) proposed a model for attitudes toward science, based on Bloom's (1976) prediction and theory, incorporating students' perceptions of past performance in science, expected future performance in science, perceived usefulness of science, and enjoyment of science. In addition, Oliver and Simpson (1988) explored the relationship between attitudes toward science, achievement motivation and science self-concept with science achievement. These studies, when considered together, found aspects related to student identity (i.e., past performance and self-concept) to be predictors of science achievement,[11] but despite favoring the inclusion of such internal factors, in fact, the opposite will be argued. Whether the researcher is interested in student achievement, their intentions to

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[10] It is worth highlighting that studies dealing with identity employ an array of related terms (e.g., self-esteem, -efficacy, -concept, -image, -perception, etc.). Undoubtedly, inconsistent and poorly articulated uses of these terms only compound the research into the already ill-defined construct of attitudes toward science.

[11] Oliver and Simpson's (1988) data was a subsample of the longitudinal study discussed reported in Simpson and Oliver (1990). The researchers concluded student self-concept impacted achievement as indicated in Figure 2.

take an elective science course, or decision to a science-related career, they need to make an essential selection—about the focal factors in their study. With no model championed by researchers in the field for use in interpreting internal factors as they relate to student preferences and engagement in science, it is difficult to abandon the well-articulated TRAPB which has displayed, at least some, value as an explanatory theoretical framework. This is certainly not an attempt to dismiss the role of internal factors, but to simply say at this time it seems more prudent to focus elsewhere.

Summary. This short overview of frameworks in the literature illustrates the need for continued work with theory by researchers in the field. In the past, attitude research was characterized as chaotic (Peterson & Carlson, 1979), partially in reference to the struggle to define and conceptualize attitudes toward science by researchers in the field. Messick (1989) highlighted that a robust, well-articulated theoretical framework for relating students' attitudes to other variables of interest was imperative. For a variety of reasons, none the least being the fragmented history of research into students' attitudes toward science, many models were never fully explored. In the cases of Haladyna and Shaughnessy's (1982) model and Simpson and Oliver's (1990) model it is clear that a limited number of findings were ever applied to their respective frameworks. While some might try to argue that the same is true of the TRAPB model, the fact that it has attracted a committed group of researchers (e.g., Koballa, Crawley, Coe, and others) and been recognized by the science education community at large (e.g., Osborne et al., 2003) speaks to its current position.

To advance the field, and further explore the TRAPB model, two important steps are needed. The first step involves investigating the relationships and subconstructs suggested by the model in greater detail. To enable this step it is important to note that a well-crafted, valid instrument is required that addresses each of the proposed constructs. The second step is to test the TRAPB model as whole, gathering information about students' behavioral intentions and following up to see what behaviors actually occurred. Obviously, as previously discussed, the overall goal of the second step is to see if students' behavioral decisions relating to science engagement can be predicted. The more practical value of understanding of the causal sequence implied by the TRAPB, as Osborne et al. (2003) note, is that it may help determine what salient beliefs students hold and how they impact decision-making. Those beliefs that students might hold, for example "girls don't do science," can then be specifically targeted to affect relevant behavioral decisions by either reinforcing or combating these beliefs.

The present study addresses the first step, mentioned above, of advancing research using the TRAPB model by refining and validating an instrument to assess students' attitudes toward science. Up until now no other instrument has been designed and validated for use in the United States with the TRAPB in mind. The recently developed ASSASS instrument (Summers, 2012) was rigorously designed, grounded in the TRAPB framework, and ready for validation. A summary of how the instrument reflects the TRAPB model, including how its various subconstructs are thematically represented, is presented in Chaper III. To better orient the reader to aspects of measurement in this field, the following section will provide an overview of instruments that have been used to gauge students' attitudes toward science. This serves to illustrate the limitations of many extant instruments and to expand on the need for a new instrument.

Assessing Students' Attitudes toward Science

Early in the history of research into the influence of affective variables, educators were challenged to think more scientifically about the measurement of scientific attitudes and attitudes toward science (Noll, 1935). In an attempt to meet this goal a number of instruments have been developed over the years with the intention of accurately assessing affective variables among students. Quantitative measures aiming to measure student attitudes toward science vary in several ways, such as their specific focus, number of questions, and target age range. Despite these differences, the instruments most commonly employed share a number of similarities. Before discussing instrument characteristics in depth, it is first important to consider how intended use and study design place certain restrictions on an instrument.

The case for cross-sectional study. The relationships between students' attitudes toward science and other factors reported in previous sections are the product of numerous studies, spanning more than 40 years, piecemealed together. Many extant studies, though important to the advancement of the field, involved single, small-scale data collection efforts (e.g., Hamrick & Harty, 1987). Moving forward it is imperative to build on these works by adding both breadth and depth. Few attempts have been made to add depth to the body of research in this field by taking a longitudinal approach to studying students' attitudes (Oliver & Simpson, 1988). The benefit of a longitudinal study is that researchers are able to detect developments or changes in the characteristics of the target population at both the group and the individual level. Because longitudinal studies extend beyond a single moment in time they can establish sequences of events. This is a huge boon, as demonstrated by George (2000) who used a national longitudinal database to collect information about students' attitudes toward science and confirmed the findings of other longitudinal studies in the field (e.g., George & Kaplan, 1998; Simpson & Oliver, 1990). George's work supported the existence of a declining trend in students' attitudes toward science, one of the more concerning trends to come from this field of research and one that cannot be detected outside of longitudinal design. The scarcity of research of this kind is almost certainly related to issues associated with long-term commitments, as longitudinal studies of this kind require several observations of the same subjects over a period of time. Not only do lengthy studies involving students require tremendous support from teachers and schools, but they can easily succumb to problems such as cost and attrition.

The disparity of studies aiming for depth is matched by the disproportion of studies seeking breadth. Compared to longitudinal studies, cross-sectional studies generally focus on a single point in time compared to longitudinal studies that take place over a longer span (Vogt & Johnson, 2011). Instead, cross-sectional designs (Gall, Borg, & Gall, 2002) involve comparing current individuals at different stages on the variable of interest (e.g., age). An advantage of cross-sectional designs is that results become available more quickly. Studies incorporating such designs also mitigate some of the notable complications of longitudinal studies (e.g., cost and attrition). Without the need to cultivate a long-term relationship with schools, as would be desirable for longitudinal work, cross-sectional studies allow for a far greater number of schools to be involved, across a larger geographical area, and including more diverse students (e.g., ethnicity, socioeconomic status [SES], funding of school attended, etc.). In addition, cross-sectional designs do not greatly increase in burden by including a wider age range of students. Consider the previously mentioned longitudinal studies, Simpson and Oliver (1990) involved students in grades 6-10, George and Kaplan (1998) examined eighth-grade student responses from the National Educational Longitudinal Study of 1988, and George (2000) examined grades 7-11 using part of the data collected in the Longitudinal Study of American Youth.

For research employing cross-sectional design, because the aspect of change involves time, researchers must be cautious when comparing younger and older students. In particular, it is important to be mindful of what inferences are being made, such as the effect of time. For example, it is risky to assert causal relationships with cross-sectional data, especially when claimed causes and consequences are measured at the same time (“Institute for Work & Health”, 2009). The evidence it offers about the effect of time is indirect. In this context, it would be incorrect to describe grade-level differences as showing “declining” attitudes. It is also risky to assert causal relationships with cross-sectional data, especially when claimed causes and consequences are measured at the same time. Just because differences are noted, it does not indicate that the experience of the group on one end of the spectrum will be similar to the group on the opposite end or vice versa (Vogt & Johnson, 2011). With these considerations in mind, and more so the contribution it offers to the field, the present study will employ a cross-sectional design to collect responses from Illinois students. Proceeding into discussion about instrument characteristics it will be essential to identify those characteristics that best correspond to the design of the present study.

Measures of students’ attitudes toward science. To introduce the reader to the expansive library of instruments available in the research, a summary overview is provided (Table 1). The discussion that follows will emphasize how the characteristics of extant instruments impact their performance and usefulness. Table 1 reveals that the larger majority of the existing quantitative measures of student attitudes toward science employ Likert-type scales. Many instruments, such as the Children’s Science Curiosity Scale (Harty & Beall, 1984) and the Simpson-Troost Attitude Questionnaire, Revised (Owen, Toepperwein, Marshall, Lichtenstein, Blalock, Liu, et al., 2008), go with the 5-point scale, with responses ranging from strongly disagree to strongly agree. Germann (1988), citing Fishbein (1967), comments on the prevalence of this response pattern by explaining that the Likert technique is intended to measure the strength of individuals’ attitudes. In some cases, instruments designed to be used with younger students (Harty & Beall, 1984; Pell & Jarvis, 2001) included illustrative images (e.g., smiley faces) to help them respond. Note that some researchers have designed alternate response

Table 1

Summary Overview of Selected Attitude Instruments

Developer(s) and instrument	Focus[a]	Target audience	Format	Reference to theory[b]	Sample questions
Fraser's (1978) Test of Science Related Attitudes (TOSRA)	Perceived utility of science, attitudes toward science as a school subject, pursuing science, and science as leisure	Students grades 7 through 12	70 items on a 5-point Likert scale	Yes	Scientific studies are doing more harm than good. Science lessons bore me. I dislike reading newspaper articles about science.
Germann's (1988) Attitude Toward Science in School Assessment (ATSSA)	Attitudes toward science as a school subject	Students grades 7 and 8	14 items on a 5-point Likert scale	Yes	Science is fun. I would like to learn more about science. Science makes me feel uncomfortable, restless, irritable, and impatient.
Halloun's (1997/2001) Views about Science Survey (VASS)	Science self-concept, Attitudes toward science learning, nature of scientific knowledge, and perceived usefulness of science.	Students grades 8 through 16	30 items on a 5-point scale toward one of two statements. Five overlapping versions available for different branches of science	Yes	I study physics: (a) to satisfy course requirements (b) to learn useful knowledge 1. Mostly (a), rarely (b) 2. More (a) than (b) 3. Equally (a) & (b) 4. More (b) than (a) 5. Mostly (b), rarely (a)
Hartly and Beall's (1984) Children's Science Curiosity Scale (CSCS)	Attitudes toward science-related activities, Attitudes toward doing science	Grade 5 students	30 items on a 5-point Likert scale using emoticons	Yes	I like to watch television programs about science. It is boring to read about different kinds of animals.
Misiti, Shrigley and Hanson's (1991) Science Attitude Scale (SAS)	Attitudes toward school science learning, attitudes toward science-related activities	Students grades 5 through 8	23 items on a 5-point Likert scale	Yes	I wouldn't think of discussing science with my friends outside of class.

(continued)

Table 1 (continued)

Developer(s) and instrument	Focus[1]	Target audience	Format	Reference to theory[2]	Sample questions
Misiti, Shrigley and Hanson (cont'd)					I hate keeping records of experiments in a lab notebook. Learning science facts is a drag.
Weinburgh and Steele's (2000) modified Attitudes toward Science Inventory (mATSI)	Attitudes toward science, anxiety toward science, perceived usefulness of science, science self-concept, perception of science teacher	Grade 5 students	25 items on a 5-point Likert scale	Yes	I feel at ease in science class. No matter how hard I try, I cannot understand science. Science is something I enjoy very much.
Siegal and Ranney's (2003) Changes in Attitude about the Relevance of Science (CARS)	Attitudes toward school science, perceived usefulness of science	Middle and high school students	20 items on a 5-point Likert scale. Three versions of the instrument available, 8 questions overlap.	Yes	Learning science will have an effect on the way I vote in elections. My parents encourage me to continue with science.
Simpson-Troost Attitude Questionnaire as revised (STAQ-R) by Owen et al. (2008)	Attitudes toward school science, perceived attitudes of family, perceived attitudes of peers	Students grades 6 through 8	22 items on a 5-point Likert scale in the revised version	Yes	I enjoy science courses. Most of my friends do well in science. My mother likes science.
Sjøberg and Schreiner's (2005) Relevance of Science Education (ROSE) Student Questionnaire	Attitudes toward science, attitudes toward specific topics and activities, science self-concept, perceived usefulness of science	Students 15 years of age	250 items with varying scales (Likert, agree/disagree, interested/not interested, often/never)	Yes	I would like to learn about… Stars, planets, and the universe Science and technology are important for society
Pell and Jarvis's (2001) instrument to assess children's attitudes toward science	Attitude toward school, attitudes toward science, perceived usefulness of science	Students grades 1 through 6	43 items scored on a 5-point Likert scale using "smiley" face emoticons. Only	Not present	How do you feel about . . . Doing science experiments. Watching the teacher do an experiment.

positively worded
items were included.

(continued)

Table 1 (continued)

Developer(s) and instrument	Focus[1]	Target audience	Format	Reference to theory[2]	Sample questions
Wareing's (1982) Attitudes toward Science Protocol (WASP)	Attitudes toward school science, science self-concept, perceived usefulness of science,	Students grades 4 through 12	42 items on a 5-point Likert scale	Not present	I am sick of the "hows" and "whys" in science. Students are like robots in science classes.
Gibson and Chase's (2002) Science Opinion Survey (SOS)	Attitudes toward school science, attitudes toward scientists	Students grades 6 through 8	30 items on a 5-point Likert scale	Not present	I would like to be a scientist when I leave school. Science lessons are fun.

[a] These identifiers do not necessarily reflect specific constructs or categories noted by the author(s). These terms were assigned thematically, based on the focus of multiple items.

[b] This column indicates that a theory was referenced in the design of the instrument. It does not reflect the extent (ranging from operational definitions of key terms to full model), nor does it comment on the viability, of the reference made by the author(s)

formats. For example, based on Aikenhead and Ryan's approach (1992), Halloun (1997/2001) designed the response format for Views about Science Survey so that it included both evaluation and explanation. This format might be very informative for answering select research questions, but it would likely add unnecessary complications when surveying large, diverse populations.

Of all of the characteristics listed on Table 1, two that must be considered by researchers intending to implement an instrument are the age level of the target student audience and the length of the survey. The range of questions contained within existing instruments varies widely with some utilizing fewer than 15 items (e.g., Attitude Toward Science in School Assessment; Germann, 1988) and others in excess of 200 items (e.g., Relevance of Science Education; Sjøberg & Schreiner, 2005). While there are not any hard and fast rules regarding survey length, it is important to keep in mind that too many questions can increase respondent burden and item nonresponse (Heberlein & Baumgartner, 1978). This is particularly concerning for studies involving young students, as they may be more prone to survey fatigue.

The intended target audience also varies between instruments. Some instruments are designed to target a single grade level (e.g., Children's Science Curiosity Scale [Hartly and Beall, 1984]), or specific age of students (e.g., Relevance of Science Education [Sjøberg & Schreiner, 2005]). Other instruments target a grade-level range, such as middle or high school (e.g., Heikkinen, 1973; Skinner & Barcikowski, 1973). Instruments that accommodate a range of grade levels generally extend from either the low to the middle grades, or from the middle to the high grade levels. Note that the only instrument included in Table 1 designed for participants in elementary, middle, and high school is the Wareing Attitude Toward Science Protocol (Wareing, 1982), but it falls short in other regards (e.g., absence of a theoretical framework).

Continuing with the discussion about instrument characteristics, it is notable that the degree attitude toward science is addressed and additional concepts are emphasized vary. Some extant instruments focus strongly on a single aspect, such as the Attitude toward Science in School Assessment (Germann, 1988), while others are more generalized, such as the Science Attitude Inventory: Revised (Moore & Hill Foy, 1997). One limiting characteristic of instruments, functioning similar to age, is the presence of advanced science content or discipline-specific terminology. To explain, most students could honestly respond to general questions, such as “I enjoy science courses” (Owen et al., 2008), on a Likert scale. However, some students might not know enough about Physics, in this case, to articulate how “the laws of physics portray the real world” (Halloun, 1997, 2001). If an instrument did ask questions about advanced topics, care would need to be taken to ensure that the respondents had the prerequisite knowledge to appropriately respond or, if not, a way to report their uncertainty.

Criticisms of attitudes toward science instruments. Attempts to measure student preferences or characterize affective responses to science have met a variety of challenges. Several studies (e.g., Gardner, 1975; Munby, 1983; Schibeci, 1984; Shrigley & Koballa, 1992) have highlighted these issues, and Ramsden (1998) offers a succinct summary. Two of the issues raised, which have been presented and discussed in previous sections, relate to the imprecise definitions of key terms and the inconsistent use of theory in interpreting attitudes. This section will address issues raised by Ramsden, and many others, regarding instrumentation. These weaknesses in extant measures as indicated by the research literature, as Ramsden describes, include:

- Poor design of instruments used to gather data and of individual response items within instruments.

- Lack of standardization in the wide range of instruments reported as a means of measuring “attitudes” makes comparisons between studies problematic.
- Failure to formulate the research with reference to theory on the construction of data collection tools.
- Failure to address matters of reliability and validity appropriately.

Note that many of the problems highlighted above persist because of a documented tendency for researchers to haphazardly design their own measures for various pursuits (Blalock et al., 2008). So while much of the blame for the problems with capturing and interpreting student attitudes has been placed on inadequate instrumentation (e.g., Gardner, 1975; Munby, 1979; Pearl, 1974), researchers have done little to improve extant instruments and advance measurement practices in the field. The following sections will elaborate on the weaknesses Ramsden noted about extant instruments.

Poor design of instruments. Critiques of extant instruments have raised issues with the item creation and/or selection process. In general, a cursory review of extant instruments reveals that numerous items that are poor for the selected response format (i.e., Likert scale) are poorly worded. As examples, compound items (“Science makes me feel uncomfortable, restless, irritable, and impatient” [Germann, 1988]) and items that incorporate confusing terms (e.g., “Students are like robots in science classes” [Wareing, 1982]) are unreliable. Munby (1982) highlighted additional issues associated with the over-reliance on advisory panels for establishing face validity of an instrument, a common practice in the development of several measures of attitude and interest (e.g., Germann, 1988) emphasizing that the meanings attributed to the items by the panel members will not be the same as those attributed by the participants. Osborne et al. (2009), in an effort to circumvent such pitfalls, advocated the use of participant interviews following survey administration to examine how respondents interpreted questions and why they selected a given response.

Wide-range of "attitude" measures. Recall that attitudes toward science have historically been ascribed a number of meanings. Blosser (1984) noted that "attitudes toward science" can be used to reference scientific attitudes and interests, as well as attitudes toward scientists, scientific careers, methods of teaching science, science curriculum, or the subject of science in the classroom. This definition encompasses a number of intricate constructs, which may be defined or framed in different ways depending on the purpose and perspective of the researcher(s) involved. Unsurprisingly, several of these meanings are reflected in various measures of attitudes toward science. This variation in ascribed meaning and associated measures has been noted in reviews of the field (e.g., Haladyna & Shaughnessy, 1982; Schibeci, 1984). The concern with such widespread meanings is that the applicability and comparability of research outcomes can be limited. To demonstrate, first recall that students' attitudes toward science have been found to moderately correlate with science achievement (Osborne et al., 2003). Now, consider that Marsh (1992), in a study of Australian boys in grades 8 and 10, reported a strong relationship ($r = 0.70$) between attitudes and science achievement. Without a clear articulation of the attitude construct, these correlations might appear comparable. In reality, such a comparison would be fallacious as Marsh categorized attitude as a component of self-concept and utilized a measure which only considered internal variables. This example highlights the necessity of the clear articulation of attitude and associated constructs, as well as the need for transparency in their assessments, in order to contribute to a collective body of knowledge.

Incorporation of theory in instrument construction. Critiques of existing instruments have drawn attention to the necessity of clear conceptualization and a robust, well-articulated theoretical framework (Messick, 1989). Gardner (1975) also spoke to the need for clarity, especially as it relates to terminology. Many of the issues plaguing instruments, with regard to theory and terminology, are consistent with the concerns raised in earlier sections (e.g., absent or ambiguous frameworks and definitions). This is demonstrated by the relatively little insight provided, by researchers purporting to utilize the previously discussed theoretical frameworks, into the application (e.g., Crawley & Coe, 1990) or interpretation (e.g., Haladyna & Shaughnessy, 1982) of the framework in question. Pearl (1974) warned that the validity of a given measure may be highly suspect without a corresponding definition, explanation, or conceptualization. The Wareing Attitudes toward Science Protocol (WASP) embodies this concern, boasting very high reliability estimates (0.91-0.94) without giving consideration to theory.

Concerns of consistency, reliability, and validity. Researchers (e.g., Krynowsky, 1988; Munby, 1983; Pearl, 1974; Ramsden, 1998) have been very critical of some extant measures of student attitudes and interests in science for lacking sound evidence in terms of validity and reliability. Munby (1979) criticized the validity and credibility of instruments seeking to quantify affective outcomes of science education, claiming that existing instruments do little to “enlist our confidence in their use” (p. 273). Gardner (1975) identified internal consistency and uni-dimensionality as key statistical criteria for instrument development. In fact, few instruments purporting to measure students’ attitudes toward science were found to demonstrate exceptional internal consistency, reliability, and/or external validity in the comprehensive review conducted by Blalock et al. (2008). Osborne and colleagues (2009) go on to note in their review of literature that efforts to establish instrument validity and reliability have been poor in multiple cases.

Blalock et al. (2008) echoed this finding and pointed out numerous cases in which instruments failed to meet the minimum standards of modern psychometric evaluation.

Many of the instruments, which are still the basis for current research were developed in the 1970s and 1980s (e.g., Fraser, 1978; Germann, 1988; Moore & Sutman, 1970; Simpson & Troost, 1982). As such the concerns voiced by Blalock and colleagues (2008) has even greater magnitude, stressing the need to update psychometric tools used in the field. Owen et al. (2007) demonstrated the potential for re-evaluating extant instruments, by using factor analysis to refine the Simpson-Troost Attitude Questionnaire (Simpson & Troost, 1982) to a five-factor model. Such potential for refinement illustrates the merit, and necessity, of modern psychometric analyses in the instrument development process. However, to also address additional issues with existing instrumentation (e.g., problems with underlying theoretical framework) it might be justifiable to instead develop an instrument from the ground up and systematically tackle each issue.

Summary. At the beginning of this section it was established that the present study would employ a cross-sectional design (Gall, Borg, & Gall, 2002) to compare students of different ages in Illinois in terms of their attitudes toward science. The rationale for this selection was that cross-sectional studies, compared to longitudinal studies, allow for the inclusion of a greater number of schools, across a larger geographical area, with increased student diversity (e.g., ethnicity, SES, funding of school attended, etc.). After establishing the study design, it was then necessary to select an instrument to be administered to students. Selecting an instrument for students in grades 5 through 12, a range that will be explained further in Chaper III, proved problematic for three reasons. The first, as highlighted by Table 1 and the preceding discussion, was that no existing instrument was well-suited for cross-sectional study. The second, as discussed in the latter portion of the section, is that many extant instruments suffer from an assortment of problems that have been the focus of prominent reviews (Blalock, et al., 2008; Osborne, et al., 2009). Some concerns with instrumentation, namely issues with their item composition, construction, and validity, could be addressed in extant instruments as demonstrated by the work of Owen et al. (2008). However, instrument shortcomings with respect to the poor articulation, or even absence, of a theoretical framework, or other relevant definitions, cannot be easily rectified. The third problem that needs to be resolved is that an instrument selected would need to incorporate a well-articulated, robust framework. Ideally, building on the discussion from the previous section, this framework should reflect the dominant perspective of the field (i.e. the TRAPB).

Discussion

Much of the attention to attitudes in science education research is rooted in the belief that affective variables are as important as cognitive variables in influencing learning outcomes, career choices, and use of leisure time (Koballa, 1988a). Several investigators have engaged the problem of declining attitudes and interests, and the subsequent resulting undesirable outcomes, with the underlying hypothesis that attitudes help to steer school performance and career choice (e.g., Cannon & Simpson, 1985; Germann, 1988; Wyer, 2003). Assessing the significance and importance of attitudes can be difficult, as they are essentially a measure of a person's expressed preferences and feelings towards an object (Osborne et al., 2003). Educational researchers operate under the assumption that students develop a number of particular preferences during their formative years. By better understanding how these preferences are formed and the changes they undergo, researchers in this field aim to affect relevant behavioral decisions by students (e.g., electing to take additional science courses and/or pursue science-related careers). To advance the field to the point where this approach is feasible requires a firm understanding of the factors that influence students' preferences and a means to assess whatever preferences they currently hold. The first requirement has been met by the adoption of the causal TRAPB model (Fishbein & Ajzen, 1975) by the field (Osborne et al., 2003) as means of explaining how students' attitudes and perceptions ultimately shape their intentions.

Further advancing the field, utilizing the TRAPB as a theoretical model, requires work in a two-stage plan. The first stage of this plan involves investigating the relationships and subconstructs suggested by the TRAPB in greater detail. The literature is convergent on a number of patterns related to students' attitudes toward science (e.g., attitudes decline as students get older [Pell & Jarvis, 2001]) and also nominates a number of factors that influence these attitudes. For these patterns, additional research is needed to understand which of these factors (e.g., individual characteristics, influence of the science teacher, and perceived usefulness of science) are most formative of students' attitudes and, possibly, govern student intent to engage with science in the future. Other factors noted in the literature (e.g., home environment and peers) that have not had their influence examined within the model suggested by the TRAPB (i.e., subjective norm and student's motivation to comply) merit additional study as well.

Many past studies investigating students' attitudes toward science and related factors have been limited. The majority of extant research is based on small scale studies (e.g., Hamrick & Harty, 1987), and though many of the identified patterns have been substantiated by the few longitudinal studies conducted (e.g., George, 2000), these studies often allow for very little student diversity. Taking a cross-sectional approach in future work would complement this foundation of research. The present study employed a cross-sectional design to determine the landscape of Illinois students' attitudes toward science, across their school experience with age as the variable of interest. Accessing an assorted sample of students (e.g., ethnicity, SES, funding of school attended, etc.), from several schools, across the state of Illinois, will allow the patterns reported in the literature to be examined in light of their diversity.

To enable the cross-sectional study of Illinois students' attitudes toward science it was obvious that an appropriate instrument, that addressed each of the proposed constructs of the TRAPB, was required. A thorough examination of the literature revealed that no existing instrument was suitable for the task. Prominent reviews (Ramsden, 1998; Blalock et al., 2008; Osborne et al., 2009) highlight that extant instruments are rife with problems which include, as a few examples, flawed construction, poorly articulated theory and constructs, and absent or inaccurate validity information. In addition, the single existing instrument that was designed to cover the desired grade range for this longitudinal study (i.e., grades 5 through 12) did not reference any relevant theory, let alone the dominant theory of the field (i.e. TRAPB). In light of this disarray, as a response to the clear need for a well-crafted instrument, this study details the refinement and validation of a recently developed instrument (i.e. the ASSASS), addresses the failings of past instruments noted in the literature, and aligns to the current theoretical perspective of the field.

Student responses to the ASSASS instrument enable the causal model suggested by the TRAPB to be examined in greater detail. Note that the design of the present study, involving data collection at a single point in time, does not allow students' intentions to be assessed and then to be later examined for accuracy. However, student responses will provide information about the individual subconstructs and relationships between them. To further consider some additional factors that are less distinct in the TRAPB, though included in other models (Haladyna & Shaughnessy, 1982) and supported by the research literature (e.g., George, 2000), the present study also investigates the characteristics of the classroom teacher and science learning environment.

Conclusion

Chaper II presented a review of the research literature pertaining to students' attitudes toward science, focusing on its definition and conceptualization, noted patterns and associated factors, and issues related to measurement. Following the introduction and overview of the research questions in Chaper I, this review helped to communicate the need for the present study by offering insight into the past efforts and current perspectives of the field. Chaper III will discuss the application of this foundation, by clearly operationalizing key constructs, articulating the cross-sectional design in the Illinois context, and providing details about instrumentation.

Chapter III

Method

Purpose

The purpose of the present study was to assess Illinois students' attitudes toward science using a new, valid and reliable instrument with a cross-sectional statewide sample. The ASSASS instrument was originally developed for use in Qatar. This chapter describes the methodology and sampling used to address the following research questions:

1. What is the factor structure for the ASSASS administered to US students, and does this structure reflect the instrument's underlying theoretical framework (i.e., the TRABP)?
2. What is the landscape of Illinois students' attitudes toward science across their school experience?
3. To what extent do school characteristics, including the attributes of classroom teachers, influence student attitudes toward science across the state of Illinois?

To answer these research questions, students in grades 5 through 12 across the state of Illinois completed a survey about their attitudes toward science, perceptions of science learning, and intentions to pursue science learning and/or careers in the future. A recently developed quantitative attitude assessment measure, the ASSASS, was selected for use because its content and design were compatible with the aims of this study. Additional information about the characteristics of the participating classes and the performance of the schools they were nested within were collected from a variety of sources. Teachers of the participating classes were also surveyed to provide further insight into the science learning context of participant students. Research questions 1 and 2 relied heavily on the student responses collected, while research question 3 was intended to take data from multiple sources into account. Toward this end, these data sources were carefully selected so that multi-level modeling could be used respond to the latter question.

Method

A statewide representative sample of Illinois students and their teachers was selected to participate in a cross-sectional study focused on students' attitudes toward science. Students in grades 5 through 12 were administered the 59-item US-ASSASS instrument intended to gauge precollege students' attitudes toward science and science learning. Teachers of participating class sections were administered a 25-item Science Teacher Survey that inquired about their individual characteristics, practices, and other classroom variables, which could impact students' attitudes toward science. The surveys were made available for students and teachers to complete online. Additional information about the schools included in the sample was gathered from the Illinois Report Card available from the Illinois State Board of Education (ISBE) and National Center for Educational Statistics.

Context of the Study

There are two aspects of the Illinois context that are essential for framing the study. The first relates to the state geography and culture. The largest population center in Illinois comprises Chicago—the third largest city in the United States, and the surrounding metro area, which include several counties in the northern part of the state. The rest of Illinois is much more rural when compared to the densely populated and industrialized Chicago area, characterized by small towns and small to medium cities. Exceptions to this characterization exist in northern (e.g., Rockford), central (e.g., Champaign-Urbana), and southern Illinois (e.g., East Saint Louis). The predominantly rural stateside; however, influences a number of school-related attributes such as racial composition and level of income.

Overall, students attending public schools during the 2011-2012 academic year in Illinois were 0.3% American Indian/Alaska Native, 4.2% Asian, 18.2% Black/African American, 0.1%

Native Hawaiian/Other Pacific Islander, 23.6% Hispanic/Latino, and 50.7% White, with 2.9% having reported two or more races (ISBE, 2012). Ninety percent of Illinois students attend public schools, and 49% are identified as low-income (ISBE, 2012). The geographical distribution of urban areas in Illinois clusters student diversity and family income, thus, heavily skewing the composition of schools. Chicago Public Schools (CPS), with an enrollment of over 375,000 K-12 students, reported the following racial make up for the 2013-2014 school year: 0.3% American Indian/Alaska Native, 3.6% Asian, 39.3% Black/African American (versus 18.2% statewide), 0.2% Native Hawaiian/Other Pacific Islander, 45.6% Hispanic/Latino (versus 23.6% statewide), 9.4% White (versus 50.7% statewide), and 1.1% having reported two or more races (Office of Accountability, 2014). Additionally, 85% of CPS students are designated low-income and 16.3% are English language learners. Notice that the racial distribution of CPS differs from the statewide proportions with nearly double the representation of Black/African American and Hispanic/Latino students. In comparison, Effingham Public Schools, representing approximately 5,500 K-12 students feature the homogeneity common to downstate Illinois with 96% of students categorized as White (Public Schools K12, 2011).

Geographical distribution of student diversity in Illinois is coupled with substantial variance in terms of school funding across the state. Such variance derives from the structure of the Illinois property taxes, which serves as a major source for K-12 education funding. This tax is local and imposed by local governing bodies (some corresponding to a single school district). Thus, tax revenues and associated school funding varies widely across the state (Biles, 2005). As a consequence, public schools in urban and rural areas have noticeably less funding available (Black, 2011), especially when compared to more affluent regions of Illinois.

The state of Illinois, like many other states, is in a period of transition due to the incorporation of new standards. Illinois has shown a strong commitment to standards-based learning through its adoption of the *Common Core State Standards* in 2010. These standards were introduced to Illinois classrooms in the fall of 2012 and fully implemented during the 2013-2014 school year (Common Core IL, 2013). Illinois showed a similar commitment to the *Next Generation Science Standards* (NGSS Lead States, 2013) by serving as one of 10 lead states during the development of the standards (Illinois Lead State Summary, 2011). The state is continuing with the adoption of NGSS in 2014, which will be fully implemented by during the 2016-2017 school year. The current Illinois Learning Standards were adopted in 1997. These standards are organized by four levels: Early elementary, late elementary, middle/junior high school, and late high school. Under these standards, districts in Illinois were allowed to choose their own science curriculum as long as it follows the state standards. Standardized assessments in science were administered to students in grades 4 and 7 using the Illinois Standards Achievement Test (ISAT) and in grade 11 using the Prairie State Achievement Examination (PSAE). Even with the implementation of NGSS in Illinois, the ISAT testing continues to follow a similar pattern when it comes to science. Because students are not tested in science until grade 4, it is likely that they receive little by way of formal science instruction in preceding grades. Another important benchmark with respect to students' science instruction occurs in grade 11. Illinois students are tested in science on the ISAT in grade 11, but it is possible for students not to be enrolled in a science course at that time. To graduate from an Illinois public high school students must complete a minimum of two years of science coursework with no specific course requirements. Therefore, it often is the case that junior and senior students elect to take only two courses. The lack of a requirement for students to complete a third science course at the secondary level may, in part, be reflected in the comparatively poor performance of eleventh grade students. Results from the 2011-2012 state achievement tests revealed that 79.8% and 79.9% of fourth- and seventh-graders, respectively, met or exceeded the Illinois State Standards compared to a paltry 51.7% of eleventh grade students (ISBE, 2012).

Sampling Procedures and Participants

Participant students and teachers were selected by generating a representative sample of class sections in grades 5 through 12 across Illinois. To achieve this selection, Illinois was divided into six geographic sampling regions, by county, as depicted in Table 2.[12] Schools from within each region were identified using the database of public school entities maintained by ISBE. To better visualize the geography of Illinois, the sampling regions are presented graphically in Figure 4.

Table 2

Regional Designations for Sampling Across Illinois

Region	Area covered by county
1	DuPage, Grundy, Kane, Kankakee, Kendall, Lake, McHenry, Suburban Cook (including the city of Chicago), Will
2	Boone, Bureau, Carroll, DeKalb, Henry, Jo Daviess, LaSalle, Lee, Marshall, Mercer, Ogle, Putnam, Rock Island, Stephenson, Whiteside, Winnebago
3	Adams, Brown, Cass, Christian, Fulton, Hancock, Henderson, Knox, Mason, McDonough, Menard, Morgan, Peoria, Pike, Sangamon, Schuyler, Scott, Stark, Tazewell, Warren
4	Champaign, Clark, Coles, Cumberland, DeWitt, Douglas, Edgar, Ford, Iroquois, Livingston, Logan, Macon, McLean, Moultrie, Piatt, Shelby, Vermillion, Woodford
5	Bond, Calhoun, Clinton, Greene, Jersey, Macoupin, Madison, Monroe, Montgomery, Perry, Randolph, St. Clair, Washington
6	Alexander, Clay, Crawford, Edwards, Effingham, Fayette, Franklin, Gallatin, Hamilton, Hardin, Jackson, Jasper, Jefferson, Johnson, Lawrence, Marion, Massac, Pope, Pulaski, Richland, Saline, Union, Wabash, Wayne, White, Williamson

[12] Urban Chicago, or rather the Chicago Public School (CPS) district, was not included in this sample.

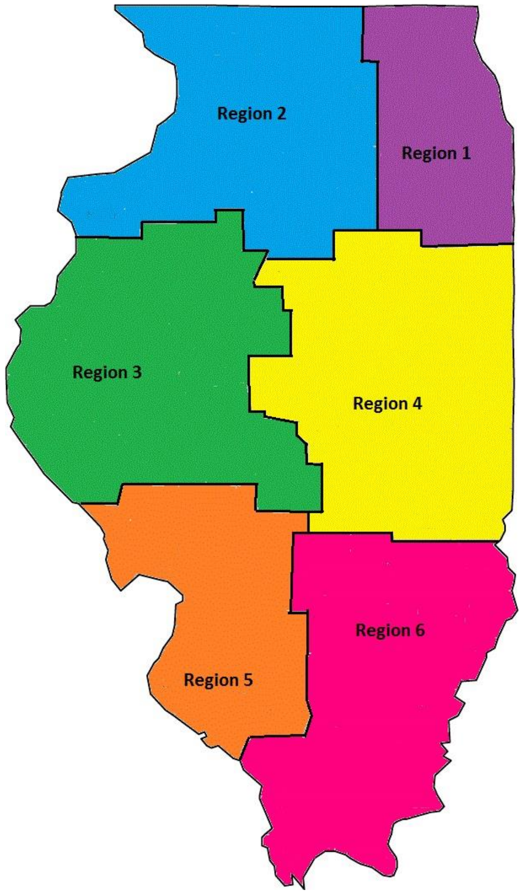


Figure 4. Geographic orientation of sampling regions across Illinois.

After identifying all public schools located in each region of the state, schools were randomly selected from these region-specific directories to generate one desired grade level per school (i.e., grades 5 through 12). Selected schools were contacted and asked if one teacher, and a single section of students from the specified grade level, were willing to participate in the study. In the event multiple sections for the requested grade existed at a particular school, school administrators and teachers were allowed to determine which section would participate in the study. In the event that a school declined the invitation to participate, or was unresponsive, another school was randomly selected from the population without substitution (i.e., unresponsive and declining schools were removed from the selection pool). The target sample for this study was 96 class sections in total. This number of sections was targeted based on the goal of recruiting two schools from each grade level, with eight levels total (i.e., 5, 6, 7, 8, 9, 10, 11, 12), from each region. In summary, the target sample was designed to include 12 schools per grade level and a total of 16 schools per geographic region.

Participant students. Data collection began in the Spring of 2014 and concluded in the Fall of 2014. The US-ASSASS was completed by 1,442 students, from 78 class sections (80.2% participation from the target sample), representing 78 unique schools. Distribution of class sections and students, by geographical region and grade, are presented below in Tables 3-4.

Table 3

Representative Sample of Illinois Students by Grade Level

	School				Students					
	Sections		Number		Male		Female		Not reported	
Grade level	*n*	%[1]	*n*	%[a]	*n*	%[2]	*n*	%[2]	*n*	%[b]
5	13	16.7	286	19.8	133	46.5	150	52.4	3	1.1
6	11	14.1	215	14.9	101	47.0	113	52.6	1	0.4
7	10	12.8	162	11.2	84	51.9	78	48.1	0	0
8	12	15.4	243	16.9	132	54.3	109	44.9	2	0.8
9	12	15.4	254	17.6	111	43.7	112	44.1	31	12.2
10	10	12.8	131	9.1	62	47.3	68	51.9	1	0.8
11	7	9.0	73	5.1	27	37.0	45	61.6	1	1.4
12	3	3.8	78	5.4	28	35.9	49	62.8	1	1.3
Total	78	100.0	1442	100.0	678	47.0	724	50.2	40	2.8

[a]Percent of grand total. [b]Percent of corresponding grade or region total.

Table 4

Representative Sample of Illinois Students by Geographical Region

	School				Students					
	Sections		Number		Male		Female		Not reported	
Geographical region	*n*	%[a]	*n*	%[1]	*n*	%[b]	*n*	%[2]	*n*	%[2]
1	13	16.7	313	21.7	146	46.6	167	53.4	0	0
2	11	14.1	162	11.2	73	45.1	87	53.7	2	1.2
3	17	21.8	322	22.3	140	43.5	151	46.9	31	9.6
4	12	15.4	199	13.8	86	43.2	112	56.3	1	0.5
5	15	19.2	252	17.5	125	49.6	124	49.2	3	1.2
6	10	12.8	194	13.5	108	55.7	84	43.3	2	1.0
Total	78	100.0	1442	100.0	678	47.0	725	50.3	39	2.7

[a]Percent of grand total. [b]Percent of corresponding grade or region total.

Note that the sample presented in Tables 3-4 does not include respondents who completed less than 45 of the content items (i.e., 75% of the total instrument items). In many cases, excluded surveys featured few, if any, completed content items. It is possible that teachers accessed the student survey prior to administering the instrument to their students. Mindful of complications that can arise when computers and the internet are required for participants to respond, it is also plausible that students could have encountered an error that required them to terminate their survey session prematurely. For cases in the sample where respondents completed more than 45 content items, full information maximum likelihood was used to deal with the missing values to the content items, allowing the most information to be utilized from the data set.[13]

Participant teachers. Out of the 78 class sections that completed the US-ASSASS, 63 corresponding teachers (80.8%) completed the Science Teacher Survey. Table 5 reports the distribution of the participating teachers according to grade level and region.

Table 5

Science Teacher Survey Respondents by Grade Level and Region

	Region 1		Region 2		Region 3		Region 4		Region 5		Region 6		Total	
Grade	*n*	%[a]	*n*	%[a]	*n*	%[a]	*n*	%[a]	*n*	%[a]	*n*	%[a]	*n*	%[b]
5	2	22.2	2	22.2	2	14.3	3	25.0	2	16.7	2	28.5	13	20.6
6	1	11.1	2	22.2	2	14.3	2	16.7	2	16.7	1	14.3	10	15.9
7	0	0.0	1	11.1	2	14.3	2	16.7	2	16.7	1	14.3	8	12.7
8	3	33.4	1	11.1	2	14.3	1	8.3	2	16.7	1	14.3	10	15.9
9	1	11.1	1	11.1	1	7.1	2	16.7	3	25.0	1	14.3	9	14.3
10	1	11.1	1	11.1	1	7.1	1	8.3	1	8.2	1	14.3	6	9.5
11	1	11.1	1	11.1	2	14.3	1	8.3	0	0.0	0	0.0	5	7.9
12	0	0.0	0	0.0	2	14.3	0	0.0	0	0.0	0	0.0	2	3.2
Total	9	99.9	9	99.9	14	100.0	12	100.0	12	100.0	7	100.0	63	100.0

[a]Represents the percentage of the total contributed by the specified region.
[b]Represents the percentage of the total contributed by the specified grade level.

[13] Full Maximum Likelihood was computed using *MPlus* and was done prior to Confirmatory Factor Analysis. See Chapter 4 for additional information.

Instrumentation

ASSASS background and development.

Theoretical framework. The development of the ASSASS instrument focused on two dimensions pertinent to the present study: Development for use with a robust theoretical framework and applicability across a range of grade levels (grades 3-12). The TRAPB theoretical model (Figure 5) is a causal, uni-dimensional model, which suggests that several variables act solely on a terminal focus: behavioral intention (un-shaded boxes).

The TRAPB framework allows student attitudes to be evaluated along with an array of influencing or contributing factors. The TRAPB model shows students' intention to perform a given behavior is determined by: (a) their attitude toward performing the behavior, which is shaped by their beliefs about the behavior; (b) their perceived approval or disapproval from important individuals, such as parents and peers; and (c) their perceived ability, which may be influenced by their assessment of the difficulty involved in performing the behavior. Despite the determinants, there may be a discrepancy between the amount of control an individual perceives to have about whether or not to engage in a given behavior and the amount of control they actually possess.

Drawing on the model presented by Fishbein and Ajzen (2005), the constructs and dimensions for the ASSASS pilot instrument (un-shaded boxes) were defined and mapped onto major elements of TRAPB (shaded boxes) as outlined in Figure 5. This mapping process was mindful of conceptual discussions about student attitudes toward science and empirical evidence from the research literature. It is important to highlight that Figure 5 also identifies additional elements, behaviors and actual behavioral controls (dashed boxes), which can only be measured through direct observation. Therefore, these elements were not addressed in the development of

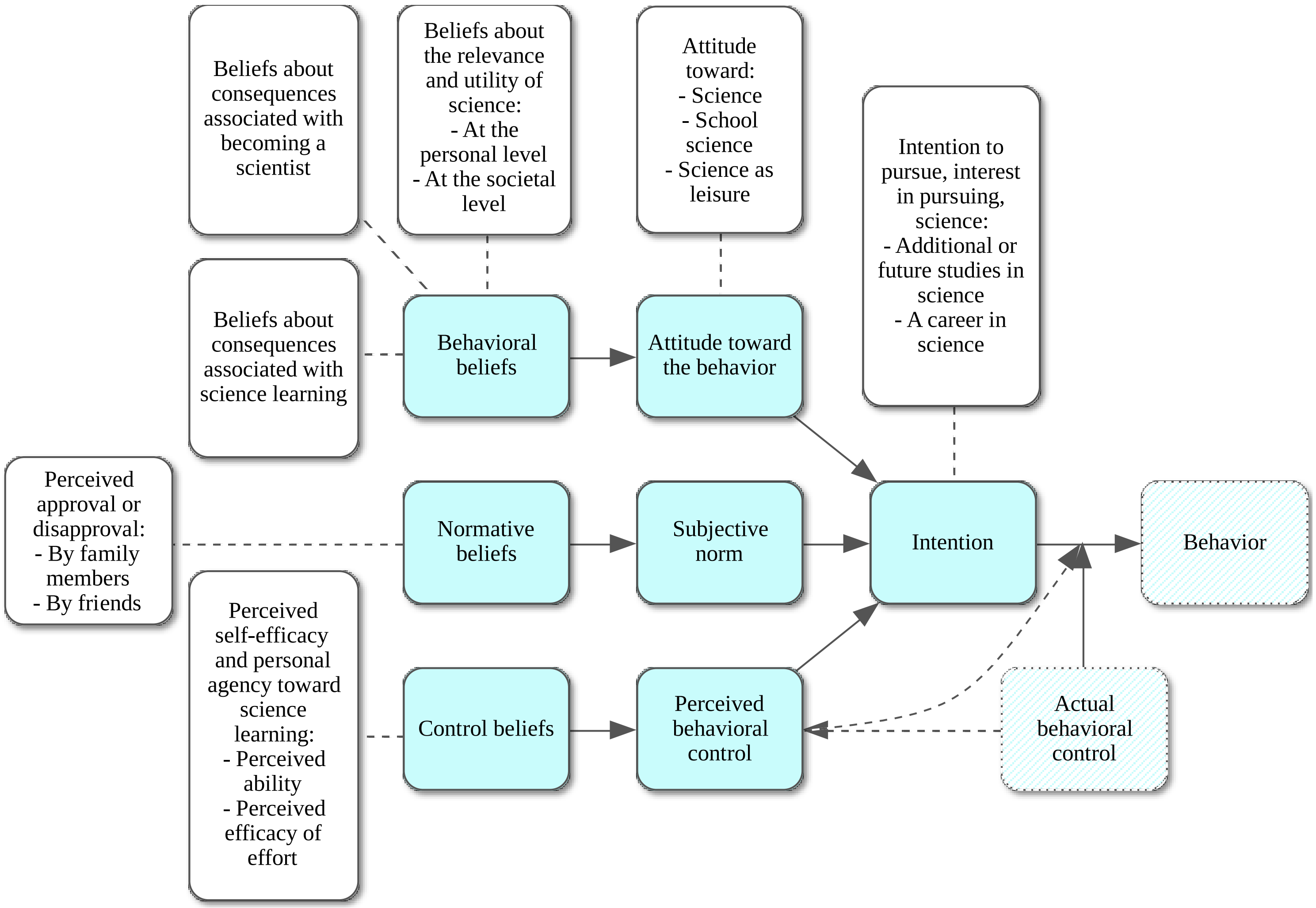


Figure 5. TRAPB model modified for use with the ASSASS. (Source: Adapted from Fishbein & Ajzen, 2005).

the ASSASS pilot instrument. Attitude toward the behavior, behavioral intention and the other major elements of the model are outlined below in Table 6.

Table 6

ASSASS Domains and Constructs as Related to Elements of the Theories of Reasoned Action and Planned Behaviors (TRAPB)[a]

TRAPB component	Definition (from Ajzen & Fishbein, 2005, p. 193)	Related ASSAS domain or construct	Related ASSAS sub-domain or sub-construct[b]	Illustrative ASSASS items[b]
Intention	Antecedent of actual engagement with the target behavior	Intention to pursue, interest in pursuing, science	– Additional or future studies in science – A career in science	– I will study science if I get into a university – I will become a scientist in the future
Attitude toward the behavior	"A learned disposition to respond in a consistently favorable or unfavorable manner toward an attitude object [in this case, science]"[c]	Attitude toward different facets of science as it relates to student lives	– Attitude toward science – Attitude toward school science – Attitude toward science as leisure	– I do not like science – I really enjoy science lessons
Behavioral beliefs	Beliefs about "the likely consequences of a behavior . . . outcome expectancies . . . or costs and benefits . . . these beliefs and their associated evaluations are assumed to produce an overall positive or negative evaluation or attitude toward performing the behavior in question"	Beliefs about the consequences associated with engagement with science, and beliefs about the benefits associated with science	– Beliefs about consequences associated with becoming a scientist – Beliefs about consequences associated with science learning – Beliefs about the relevance and utility of science: (i) at the societal level; (ii) at the personal level	– Scientists do not have enough time for fun – I look forward to science activities in class – We live in a better world because of sciences – Learning science is not important for my future success
Control beliefs and perceived behavioral control	"Beliefs concerning the presence or absence of factors that make performance of a behavior easier or more difficult . . . lead to the perception that one has or does not have the capacity to carry out the behavior, referred to . . . as self-efficacy and personal agency . . . or perceived behavioral control"	Perceived self-efficacy and personal agency toward science learning	– Perceived ability toward learning science – Perceived efficacy of effort toward learning science	– Science is easy for me – I cannot understand science even if I try hard

(continued)

Table 6 (continued)

TRAPB component	Definition (from Ajzen & Fishbein, 2005, p. 193)	Related ASSAS domain or construct	Related ASSAS sub-domain or sub-construct[b]	Illustrative ASSASS items[b]
Normative beliefs and subjective norm	Beliefs "that deal with the likely approval or disapproval of a behavior by friends, family members . . . and, in their totality . . . lead to perceived social pressure or subjective norm to engage or not engage in the behavior"	Perceived approval or disapproval toward engagement with science	– Perceived approval or disapproval by family members – Perceived approval or disapproval by friends	– My family encourages me to have a science-related career – My friends do well in science

Note. Adapted from Abd-El-Khalick et al. (2015).
[a]Note that the two TRAPB components "actual behavioral controls" and "behavior" (see Figure 5), which do not lend themselves to measurement through self-report paper-and-pencil instruments, were not addressed in the ASSASS.
[b]Domains and items that survived into the finalized instrument.
[c]From (Fishbein & Ajzen, 1975, p. 6).

ASSASS item pool. The systematic analysis of 11 published instruments affirmed the absence of a consistent, or overarching, theoretical framing in instruments that have been used to assess precollege students' attitudes toward science (Summers, 2012). The following instruments were included in this analysis: Attitude toward Science in School Assessment (Germann, 1988), Changes in Attitude about the Relevance of Science (Siegel & Ranney, 2003), Children's Science Curiosity Scale (Harty & Beall, 1984), Attitudes toward Science Inventory: Modified (Weinburgh & Steele, 2000), Science Attitude Inventory: Revised (Moore & Hill Foy, 1997), Science Attitude Inventory: Modified (Nagy, 1978), Students' Motivation Toward Science Learning (Tuan, Chin, & Shieh, 2005), Science Opinion Survey (Gibson & Chase, 2002), Simpson-Troost Attitude Questionnaire: Revised (Owen, et al., 2008), Test of Science Related Attitudes (Fraser, 1978), and Wareing Attitudes toward Science Protocol (Wareing, 1982, 1990). Patterns in terms of the topics, dimensions, and constructs targeted by extant instruments were identified through this analysis. Additionally, potential items for the ASSASS pilot instrument were nominated, where appropriate, from these extant instruments. The resulting item pool contained approximately 180 items, grouped by topic and similarity.

ASSASS item selection. Item development for the ASSASS pilot instrument proceeded in two phases. First, a three-member panel, including the researcher, a science educator, and a measurement expert, individually evaluated the potential items, being mindful of the established theoretical dimensions and constructs. This review intended to eliminate redundant items and identify items of concern (e.g., poorly worded or unclear items). The most common modification to items involved the simplification and/or clarification of compounded items. For example, the item: "Much of what I learn in science classes is useful today" (Siegel & Ranney, 2003), was revised to "What I learn in science classes is useful in my everyday life" (Summers, 2012). The panel adopted, in several cases with revision, a number of existing items that were aligned with the established theoretical framework. A total of 62 items were adopted, 16 of which were modified. Twelve additional items were also developed by the panel to ensure that all intended domains and constructs were adequately addressed. This effort resulted in a pool of 74, 5-point (strongly disagree, disagree, not sure, agree, and strongly agree) Likert scale items (Abd-El-Khalick et al., 2015).

Face and content validity. A panel of experts established the face and content validity of the instrument. Panel members were carefully selected to cover expertise with research on precollege students' attitudes toward science, science teaching and learning, and science education research. Expertise from the panel membership included five science education or science college faculty members from the United States, two experts in science education research and a researcher who is considered an authority in the domain of attitudes research in science education. Panel members were asked to provide feedback on the theoretical framework underlying the ASSASS pilot instrument, the match of each item in the pool with its respective construct or domain, the wording of each item, and the appropriateness of the language for use with a range students (e.g., elementary, middle, and high school students). Panel members also were asked to suggest revisions for an item in case they identified issues with its wording and also encouraged to suggest additional items in case they believed them to be was necessary.

Feedback received from the expert panel was systematically analyzed and found to primarily pertain to individual items. As a result of the feedback, of the 74 original items submitted for review, 37 items (50%) remained unchanged, 21 items (28%) were modified, 16 items (22%) were deleted, and 10 new items were added. Completion of the recommended revisions, along with further consolidation of items addressing similar constructs or domains, resulted in a 60-item version of the ASSASS. In addition to the survey items, the ASSASS instrument also included a coversheet with several items intended to collect biographical information and give additional insight into the context of students. However, because the ASSASS was previously planned for use in a country other than the United States (Summers, 2012), a few minor changes were necessary to make the demographic and background items more applicable to the target U.S. population and context. Additionally one irrelevant item, dealing with preferred language of science instruction (i.e., Arabic versus English), was deleted from the instrument. Reiterating that the ASSASS instrument incorporates items from instruments designed in, and developed for use in, the United States, these changes, overall, do not impact the content validity of the 59-item instrument (see Appendix A for a copy of the instrument as revised). For the sake of clarity, the instrument used in the present study will henceforth be referred to as the *US-ASSASS*.

Adaptation for online administration. To adapt the instrument for online use, consent information, instructions, and the content items were uploaded onto the Qualtrics® digital platform. During this process every effort was made to ensure similarity, especially concerning response format, between the online and pencil-paper versions. Content items were placed before the background and demographic items included in the instrument. Additionally, being mindful of younger participants, a couple of unique features available only to the digital version were added to make the instrument more accessible. The first feature was to restrict the number of items per page to three, making it easier for participants to focus on the items presented to them at any one time. The second feature was to upload audio files onto the survey for students to use if needed. Mindful that reading ability might vary among students, and could consequently limit participants' ability to access the survey, individual students were given the ability to listen to the survey, or portions thereof, at their computer station. At the click of a button, a "play" icon initiating the specific audio file, students could have items, or other written portions (e.g., informed consent passages), read to them in a neutral tone.

Online administration pilot. The online instrument was piloted during the fall of 2013 with multiple class sections of third and seventh grade students to determine the ease that participants had completing, as well as teachers had implementing, the US-ASSASS online survey. Students (N = 151) were sampled from two schools, third grade students (n = 45) from a public, STEM magnet primary school and seventh grade students (n = 106) from a public middle school, both near a large Midwestern university. The third grade sample included two class sections, with one section identified as gifted. The seventh grade sample included five class sections.

Students, on average, were able to complete the online survey, including the demographic and 59 content items, in 25-35 minutes. Following their completion of the survey, a subsample of students (ranging from 2 to 4) from each class section were conveniently selected and asked about their experience with the US-ASSASS and the digital platform. General questions about the instrument focused on students' understanding of the items and whether they experienced any difficulty comprehending the questions posed. Students reported that a couple of the background questions were unclear. For example, one question dealing with race and ethnicity allowed students to select multiple responses if needed. Some younger students said they did not understand the item "Which of the following best describes me," an item intended to capture information related to participants' ethnicity. Teachers present at the time of the pilot recorded student questions that arose and submitted the information to the researcher. The most common of these questions, aside from the aforementioned issues with the background questions, were due to specific vocabulary included in some survey items (e.g., motivation, respect, pursue, influence, and science "concepts").

Following the students' completion of the online pilot, teachers were asked a set of informal questions about the ease of administrating the instrument online and asked to provide feedback to improve the process. These questions focused on the practical concerns of online survey administration, such as the time required to get all students logged on to computers and directed to the correct website. One teacher who, admittedly, was not computer savvy did require some assistance to make the survey available to students. The teacher explained that she was unable to create a link to allow students easy access from their computer stations. To help alleviate the issues raised both by students and teachers, an administration support guide was developed for teachers. This guide contained a section on survey administration and another on trouble-shooting possible issues. The guide also provided a standardized set of answers for known questions and acceptable definitions for any vocabulary items that were flagged during the pilot.

The science teacher survey. Students' views, preferences, and attitudes, are shaped by a myriad of factors. Among these factors, as discussed in Chapter II, there exists a considerable body of literature highlighting the impact of the science teacher and classroom environment on students' attitudes toward science (e.g., Haladyna & Shaughnessy, 1982). The US-ASSASS instrument aims to provide insight into student preferences regarding science and science learning, but it can only offer information about influential factors from the perspective of the student. To complement student data, the teachers of participating class sections were asked to complete a 25-item Science Teacher Survey (see Appendix B). The survey, which was also made available online using Qualtrics®, was intended to document and provide insight into teacher characteristics and practices, as well as other classroom variables, that could impact students' attitudes toward science. Participating teachers were asked questions about their educational background, pre-service training, and supplemental in-service training. These items were adapted from the 2011 Science Teacher Questionnaire, originally designed for eighth grade teachers and published by the National Association of Educational Progress (NAEP). The survey also inquired about the instructional practices employed by the teacher and learning experiences he/she provided to students. Other items included in the survey potentially aimed to reveal the influence of the school setting on students' attitudes toward science. For example, one question asked about the amount of time spent on science instruction per week. A distinct advantage of surveying science teachers, rather than students, was that it could provide information about the class section of students completing the US-ASSASS instrument. These items afforded the teacher an opportunity to describe (e.g., number of students) and characterize (e.g., regular or advanced placement) the class section.

Study Administration

Administration of the US-ASSASS. The ASSASS survey was made available online, using the Qualtrics® platform, for reliable data collection across a number of schools. The researcher, in collaboration with classroom teachers and administrators, assigned a time range for each class section to complete the survey. All participant students completed the survey under the supervision of their classroom teacher during one allotted 50-minute class period. A standard protocol for administering the survey (introducing the study, securing informed consent, giving instructions to complete the survey) was provided to participating teachers in the form of a guide (Appendix C). Additionally, students were presented with the requisite consent information online before they could access the survey. Note that while the vast majority of students completed the US-ASSASS online (73 of 77 total sections), four sections requested and were provided the materials needed to submit paper-pencil responses due to difficulties securing computer access in their respective schools.

Administration of the science teacher survey. Similar to student participants, the teacher survey was made available online. Teachers were advised to complete the Science Teacher Survey near the time they administer the US-ASSASS to their students, to help ensure the accuracy of the questions relating directly to the class section surveyed. However, teachers were afforded more flexibility in completing their survey. Teachers were not required to complete the survey on the same day as their students, nor was a time limit for completing the survey imposed. Teacher participation was voluntary and they were all presented with consent information prior to accessing the survey. Cases where teachers failed to complete the survey, for whatever reason (e.g., later deciding to decline or forgetting to comply), did not cause their students' responses to the US-ASSASS to be excluded.

Supplemental Data

Additional information about participating Illinois schools was collected from the Illinois Report Card (ISBE, 2015). Variables were purposefully selected to examine characteristics of interest at the school-level, such as a school's ability to attract competitive teachers (i.e., teacher salary). Some of the variables selected included typical measures of socio-economic status (e.g., percent low income and English-language learners). To further investigate the influence of geographic location on students' attitudes toward science, information was obtained from the National Center of Educational Statistics (2015) about the type of community in which the school is located. All of the additional variables examined alongside student and teacher responses are listed, with descriptions, in Table 7.

Table 7

Additional School-Level Predictor Variables Collected From Secondary Sources

Variable	Description	Type
Percent low income[a]	Percent of students who are considered low-income based on their eligibility for free or reduced lunch.	Continuous
Instructional spending[a]	The amount spent per pupil related to instruction in this school's district. Instructional Spending per pupil includes only the activities directly dealing with the teaching of students or the interaction between teachers and students.	Continuous
Student mobility[a]	Student mobility rate is the percentage of students who transfer in or out of the school between the first school day of October and the last school day of the year, not including graduates.	Continuous
English-language learners[a]	Percent of students who are identified as English Learners (eligible for English Learner support) in this school.	Continuous
Average teacher salary[a]	Average teacher salary in this school's district. This value represents the sum of all teacher's salaries divided by the number of full-time equivalent teachers in the district. Note that each school/district is responsible for determining the meaning of "full-time."	Continuous
Community[b]	Geographic designations of schools based on the distinctions initiated in the 2000 U.S. census, defined as: *City*, a territory inside an urbanized area and inside a principal city. *Suburb*, a territory outside a principal city and inside an urbanized area. *Town*, a territory inside an urban cluster that is outside an urbanized area. *Rural*, a territory that is outside an urbanized area and also outside an urban cluster.	Categorical

[a]Obtained from Illinois Report Card (2015) for the 2013-2014 school year.
[b]Categories and descriptions from National Center for Educational Statistics (2006).

Data Analysis

The US-ASSASS student instrument was carefully designed to reflect the underlying TRAPB theoretical framework, which include hypothesized factors derived from a thorough review of extant instruments and the research literature. Confirmatory factor analysis (CFA) is a powerful statistical tool for examining the nature of, and relations among, latent constructs (e.g., attitudes). CFA is often the analytic tool of choice for developing and refining measurement instruments, assessing construct validity, and evaluating factor invariance across groups (Brown, 2006). The first step in the analysis of data collected from the US-ASSASS was to confirm the existence of the hypothesized factors using CFA (e.g., Bentler, 1989; Joreskog & Sorbom, 1989). If the factor analysis would fail to detect underlying constructs that explain sufficient variance in the measured variables or if the constructs detected were inconsistent with expectations, the construct validity of the scale is compromised (Floyd & Widaman, 1995). Given the existence of such a factor structure, one that reflects the theoretically predicted structure, the next step was to use guidelines associated with CFA to trim and modify the model to refine the instrument and its factorial structure. CFA and the subsequent refinement process will be computed for grades 5 through 10, and also for grades 5 through 12. These grade levels were selected to represent students in compulsory, and extending to possibly elective, science education courses to explore potential differences in the response patterns. The factor structure of the finalized US-ASSASS was then compared to the factor structure of the ASSASS validated in Qatar. This comparison highlights similarities between the two instruments at both the factor- and item levels. This phase of the analysis focused on the underlying factor structure, as well as validity and reliability measures for the US-ASSASS.

The second phase of analysis started with generating descriptive statistics to help characterize student responses to the instrument. Next, using student responses to the US-ASSASS, as well as data collected from teachers and other sources, suspected trends as indicated by the research literature and research questions were examined further. The ultimate goal was to create a multivariate, multilevel model to examine relationships among multiple outcomes at different levels of analysis (Templin, 2014). The steps leading up to this point involved exploratory analyses, the creation of univariate models to explore each factor on the US-ASSASS, and the construction of a final model. The consideration of multiple outcomes (i.e., multivariate) was appropriate given the multiple factors on the US-ASSASS instrument, and the nested design of the present study (i.e., students in schools within regions) encouraged multilevel considerations. Illinois students were nested within classes, by grade level, within a region. Normally the effect of enrollment in a given school would be examined in multilevel designs by educational researchers. However, in this case since few classes were sampled from any given school, this effect would have been coupled with, or rather indistinguishable from, the grade level for analysis. For analytic purposes, grade level effects were considered to be random, and regional location was treated as a fixed effect.

Chapter IV

Results

Introduction

This chapter is organized in four main sections, which address the guiding research questions (RQs). The first section describes the refinement of the US-ASSASS instrument, using the participant Illinois student responses (RQ1). This process involved both confirmatory factor analysis (CFA) to assess the statistical fit of the instrument items within theoretical factors or sub-scales, as well as the conceptual assessment of the identified sub-scales. As a result of this process, items were culled from the instrument until acceptable fit criteria had been met. The resultant factors are compared in the next section to the factor structure of the ASSASS instrument validated in Qatar. This comparison serves to support the theoretical fidelity of the US-ASSASS to the underlying TRAPB framework. The third and fourth sections of this chapter report on the descriptive and inferential statistics computed using the student responses to the US-ASSASS, along with the additional information collected from other sources, to explore the landscape of Illinois students' attitudes toward science (RQ2). The multivariate multi-level models computed as part of the inferential analyses also examined teacher and school-level characteristics in relation to students' responses to the US-ASSASS (RQ3).

Confirmatory Factor Analysis of Illinois Student Responses

CFA of responses collected from students in grades 5 through 10 to the US-ASSASS was conducted based on the theoretical factors established in the instrument design process. (Note that the same process was also conducted for student responses in grades 5 through 12. The model fit statistics are presented separately for reasons that will become clear later in the chapter.) The complete list of individual items on the US-ASSASS are listed in Table 8 and grouped according to theoretical constructs. Analyses were done using Mplus with the maximum likelihood robust (MLR) estimator option. It should be noted that MLR is appropriate for dealing with data that may not be normally distributed (Rosseel, 2010). The analyses indicated that many items did load onto factors that resembled the theoretical structure; however, the overall fit of the 59-item model was poor. Refinement of the theoretical model proceeded stepwise, based on the results from the analysis, by systematically identifying and culling ill-fitting items. The item deletion process, necessary to reach minimum fit statistics for the instrument as a whole, is detailed in the following section. This is followed by a discussion of individual items, which extends to performance on specific factors and conceptual adherence to the TRAPB framework.

Table 8

US-ASSASS Items Grouped by Theoretical Constructs

Construct		Item
Attitudes toward science	1.	I enjoy science
	11.	Science is one of the most interesting school subjects
	18.	I like to watch TV programs about science
	24.	I look forward to science activities in class
	27.	I like to learn more about science
	28.	I really enjoy science lessons
	39.	I would like to do science experiments at home
	40.	I really like science
	52.	Science lessons are a waste of time
	53.	I enjoy science lessons when I like the specific subject I am learning
	55.	I have a good feeling toward science
	58.	I do not like science
Behavioral intention	7.	I will study science if I get into a university
	17.	I will not pursue a science-related career in the future
	21.	I will become a scientist in the future
	26.	A job as a scientist would be boring
	29.	I will continue studying science after I leave school
	33.	I would enjoy working in a science-related career
	35.	I will miss studying science when I leave school
	42.	If I could choose, I would not take any more science in school
	50.	I will take additional science courses in the future
Behavioral beliefs	2.	Learning science is not important for my future success
	3.	Scientists are highly respected
	4.	We do a lot of interesting activities in science class

(continued)

Table 8 (continued)

Construct	Item	
Behavioral beliefs (cont'd)	5.	Most people should understand science because it affects their lives
	9.	Scientific discoveries do more harm than good
	12.	Teachers encourage me to understand concepts in science classes
	14.	Science classes will help prepare me for university
	16.	My science teachers are very good
	20.	Science is useful in helping solve everyday life problems
	22.	My interest in science depends on my teacher
	23.	Much of what I learn in science classes is useful in my life outside of school
	32.	We live in a better world because of science
	37.	Knowing science can help me make better choices about my health
	43.	Scientists usually like to go to work even when they have a day off
	44.	Knowledge of science helps me protect the environment
	45.	Scientific work is only useful to scientists
	46.	Science will help me understand the world around me
	49.	There is a lot of memorization in science classes
	51.	It is important to know science in order to get a good job
	54.	Scientists do not have enough time for fun
	57.	People with science-related careers have a normal family life
	59.	My science teachers motivate me to learn science
Control Beliefs	8.	I am sure I can do well on science tests
	10.	I usually give up when I do not understand a science concept
	15.	Science is easy for me
	19.	I cannot understand science even if I try hard
	25.	I can understand difficult science concepts
	31.	I am confident that I can understand science
	41.	I try to learn science even if it is difficult
	48.	If I work hard enough, I can learn difficult science concepts
Normative Beliefs	6.	I consider my family's advice about my future career
	13.	Members of my family work in scientific careers
	30.	My family encourages my interest in science
	34.	My parents influence my thinking about my education
	36.	My friends like science
	38.	My family encourages me to have a science-related career
	47.	My friends do well in science
	56.	I care about what my friends think when I consider future careers

The first step in achieving the minimum information criterion was to cull items that loaded onto incorrect factors, specifically items 14, 22, and 42, which greatly improved the model fit. Next, there were cases where an item needed to be removed from an item-pair (e.g., exclude either item 6 or 34). After these items were removed the model fit improved greatly, but still did not achieve the minimum threshold. For these selections, item complexity and content were taken into consideration. Where possible, items were retained based on their elegance and the uniqueness of their content, leading to the exclusion of items 16, 34, 47, and 59. A review of the remaining items identified those that loaded on multiple factors, which entailed deletions of items 2, 4, 23, 26, 27, 35, 36, 41, 48, 51, 52, 53, and 55. The deletion of these items was based on modification indices; a value that shows the improvement in model fit if a particular coefficient were to become unconstrained (Gatignon, 2010), by allowing the item to correlate with another factor, or otherwise be removed. Allowing items to correlate with multiple factors complicates an instrument's model, so items with large modification indices may be considered "bad" items. Beginning with items possessing the largest modification indices, indicative of the poorest items, deletions were made in a stepwise fashion until the minimum acceptable statistical fit was achieved. The model fit of the instrument, now containing 39 items, was judged according to its Root Mean Square Error of Approximation (RMSEA) of 0.04, a comparative fit index (CFI) of 0.92. It should be noted that the ideal values for the information criteria used are as follows: RMSEA should be less than 0.07 and CFI should be greater than 0.9 (Hu & Bentler, 1999).

Item-level considerations. A final review of individual item statistics and behavior revealed that items 18 and 20 loaded onto multiple factors and were, therefore, deleted. Similarly items 54 and 24 were troublesome and were preferentially deleted based on a large modification index and poor performance, respectively. Five additional items were deleted for loading poorly, with standardized loadings less than 0.32 on their respective factors. All of the items, presented in Table 9 below, included in the final instrument loaded onto constructs that were predicted based on the underlying theoretical framework, the TRAPB.

Table 9

Standardized Loadings for the Statewide Sample of Illinois Student Responses from Grades 5 through 12 (N = 1,045)

Item	Attitude	Intention	Behavior	Control	Normative
24. I really like science[a]	0.92				
15. I really enjoy science lessons[b]	0.84				
30. I do not like science	0.84				
1. I enjoy science	0.78				
7. Science is one of the most interesting school subjects[3]	0.76				
23. I would like to do science experiments at home[c]	0.54				
20. I would enjoy working in a science-related career		0.84			
16. I will continue studying science after I leave school		0.80			
28. I will take additional science courses in the future[d]		0.80			
4. I will study science if I get into a university		0.74			
13. I will become a scientist in the future		0.67			
11. I will not pursue a science-related career in the future		0.56			
27. Science will help me understand the world around me[e]			0.77		
26. Knowledge of science helps me protect the environment[e]			0.72		
21. Knowing science can help me make better choices about my health[e]			0.70		
19. We live in a better world because of science			0.64		
3. Most people should understand science because it affects their lives[f]			0.55		
8. Teachers encourage me to understand concepts in science classes			0.47		
2. Scientists are highly respected			0.45		
29. People with science-related careers have a normal family life[a]			0.44		
25. Scientists usually like to go to work even when they have a day off[a]			0.41		
18. I am confident that I can understand science				0.82	
10. Science is easy for me				0.77	
14. I can understand difficult science concepts				0.73	
5. I am sure I can do well on science tests[h]				0.71	
12. I cannot understand science even if I try hard[g]				0.69	
6. I usually give up when I do not understand a science concept				0.58	
22. My family encourages me to have a science-related career					0.80
17. My family encourages my interest in science[i]					0.75
9. Members of my family work in scientific careers[i]					0.39

Note. Items have been sequentially re-numbered.
Item(s) source: [a]From Owen et al. (2008). [b]Modified from Fraser (1978). [c]From Fraser (1978). [d]Modified from Gibson and Chase (2002). [e]Modified from Siegel and Ranney (2003). [f]Modified from Moore and Hill Foy (1997). [g]Modified from Weinburgh and Steele (2000). [h]From Tuan, Chin and Shieh (2005) [i]Wareing (1982, 1990). The remaining items were generated internally (Summers, 2012).

Final instrument. The final 30-item instrument, containing 5 sub-scales with a simple factor structure, has a good fit with a RMSEA of 0.04, a Standardized Root Mean Square Residual (SRMSR) of 0.04, a CFI of 0.95, and a non-normed index of 0.95. (Note that ideally SRMSR should be less than 0.07 and the non-normed index should be greater than 0.9 [Hu & Bentler, 1999].) The five factors, named after the theoretical constructs along with their respective range of item loadings, include: attitude toward science (.54–.92), intention to pursue or engage in science (.56–.84), behavioral beliefs (.41–.77), control beliefs (.58–.82), and normative beliefs (.39–.80). Figure 6, read from left to right, illustrates the co-variances between factors, as well as the individual item loadings and residuals. Note that the unequal item residual values support the MLR estimator use in Mplus CFA computations.

To provide a measure of how each scale performed, as a group of items, CFA-based scale reliabilities were computed for each of the five sub-scales (Table 10). Scale reliability, also referred to as construct reliability, was estimated based on the CFA results (Dillon & Goldstein, 1984; Jöreskog, 1971) and reported instead of Cronbach's alpha due to its increased dependability (Raykov, 2001). Note that scale reliability is evaluated in a similar fashion with values greater than 0.6 considered acceptable, and values between 0.7 and 0.9 considered good.

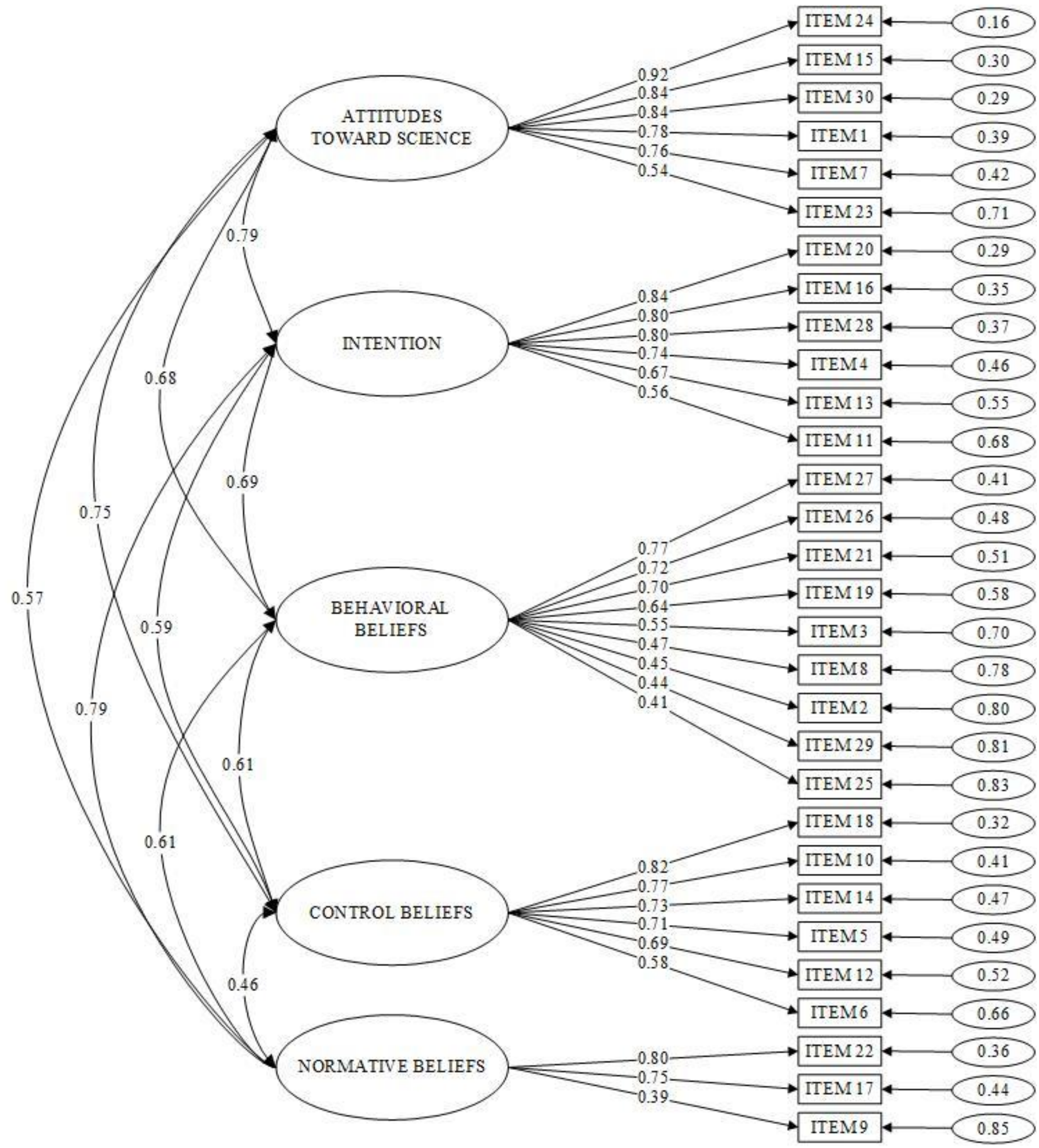


Figure 6. Standardized factor co-variances, item loadings and residuals from confirmatory factor analysis

Table 10

Scale Reliabilities Estimated From CFA Results

Sub-Scale	Reliability	Number of Items
Attitude toward Science	.91	6
Intention	.88	6
Behavioral Beliefs	.82	9
Control Beliefs	.87	6
Normative Beliefs	.70	3

Finally, to address the validity of the US-ASSASS for students in grades 11 and 12, it is important state the when computed independently, using responses from students in grades 5 through 12, the CFA and refinement of the US-ASSASS instrument resulted in the same factor structure previously presented. The same 30-item instrument model also had a good fit with a RMSEA of 0.04, a CFI of 0.95. It should also be noted that there were no drastic changes in the factor loadings of the items, generally ±0.01. Furthermore no items dipped below the minimum loading threshold of 0.32, nor were there any changes in the individual item rankings, arranged by factor loadings, compared to those presented in Table 9.

Factor Structure and Item Similarity Between Different Contexts

The same content items administered to Illinois students in this study were also administered to students in Qatar as part of a large-scale project aiming to investigate “Qatari students’ Interest in, and Attitudes toward, Science” (QIAS). One of the overarching goals of the QIAS project was to gauge Qatari student attitudes toward science, which involved the administration of the ASSASS instrument to a national probability sample of 3,027 participants representing all students enrolled in grades 3 through 12 in the various types of schools in Qatar. Of the respondents, 1,978 students completed an Arabic version of the instrument. (Note that Arabic is the official language of teaching and learning in Qatar. As such, another goal of the

QIAS Project was to develop an instrument available in both Modern Standard Arabic and English.) Responses to the Arabic version of the instrument used in Qatar were refined, in a manner similar to the instrument detailed in previous section with Illinois students, through factor analysis and the examination of individual items, both statistically and conceptually.

CFA showed that a five-factor model with similarities to the theoretical framework based on the TRAPB accounted for the Qatari responses obtained from the Arabic version of the ASSASS. Ultimately the instrument was refined to 32 items and final model demonstrated good fit, as judged by a RMSEA of 0.037, a CFI of 0.937, and a TLI of 0.931 (Abd-El-Khalick et al., 2015). The five factors demonstrated good to excellent CFA-based scale reliabilities (ranging from 0.61 to 0.87) and were designated: Attitudes toward science and science learning, unfavorable outlook on science, control beliefs about the importance of ability and effort in science, behavioral beliefs about the consequences of engaging in science, and intentions to pursue science.

The factor structures derived from responses to the US-ASSASS, by a representative sample of Illinois students, and the Arabic version of the ASSASS validated in Qatar share multiple commonalities. The US-ASSASS demonstrated considerable fidelity to the theoretical framework based on the TRAPB, as judged by the high degree to which items clustered onto predicted constructs. The Arabic version of the ASSASS, similarly, contains five coherent factors, but there is some deviation from the theoretical framework. Four of the five theoretical TRAPB constructs, to a considerable extent, are thematically represented among the factors refined in the Arabic version of the ASSASS. These four constructs, which also represent sub-scales in the finalized US-ASSASS instrument, are compared below.

First, the attitudes toward science construct was represented in both final instruments with common items, such as “I enjoy science” and “science is one of the most interesting school subjects.” The Arabic version varied slightly with its “attitudes toward science and science learning” sub-scale that also contained items related to perceptions of science learning in the school context (e.g., “My science teachers are very good”). The second construct represented in both instruments, behavioral beliefs, converged on students’ perceived utility of knowing science. Questions that represent this construct extend from basic tenets of personal understanding (e.g., “Science will help me understand the world around me”) and decision-making (e.g., “Knowledge of science helps me protect the environment” and “Knowing science can help me make better choices about my health”), all the way to perceived benefits on a global scale (e.g., “We live in a better world because of science”). The third construct, intention, is reflected in a sub-scale that is similar across both instruments. Questions included clearly link students’ plans to study science (e.g., “I will take additional science courses in the future”), extending beyond secondary school (e.g., “I will continue studying science after I leave school”), and forecasting possible future decisions (e.g., “I would enjoy working in a science-related career”).

The final construct that is represented in both instruments, control beliefs, cannot be compared as easily as the others between the two versions. While this construct is a distinct sub-scale in the US-ASSASS, it is fragmented in the Arabic version. To explain, both instruments include questions related to this construct, which center on students’ perceptions of ability (e.g., “I am confident that I can understand science” and “I am sure I can do well on science tests”). However, the US-ASSASS, with a more comprehensive control beliefs sub-scale, also includes negatively worded items that address students’ perceived limitations (e.g., “I cannot understand science even if I try hard” and “I usually give up when I do not understand a science concept”). In the Arabic version, these items instead loaded onto a separate sub-scale that includes a variety of other negatively worded items. To quantify the similarities between the US-ASSASS and ASSASS instruments, Table 11 lists the number of items in the symmetrical sub-scales from each instrument and highlights the number of shared items. Sixteen of the 30 items (53.3%) in the US-ASSASS were also in similar sub-scales in the Arabic version, and a total of 19 (63.3%) items were included in both instruments.

Table 11

Sub-Scale Comparison of Refined US-ASSASS and ASSASS Instruments

	Total items in construct			
Sub-scale	US-ASSASS	ASSASS	Overlapping items	Count
Attitudes toward science	6	9	1, 7, 15, 24	4
Intention[a]	6	6	4, 13, 16, 20, 28	5
Behavioral beliefs	9	6	19, 21, 25, 27, 29	5
Control beliefs[b]	6	2	5, 18	2

Note US-ASSASS items are numbered according to the scheme introduced in Table 9. ASSASS items are numbered according to the finalized instrument list.
[a]Item number 11 appears in the ASSASS instrument within the negative sub-scale.
[b]Items 6 and 12 also appear in the negative sub-scale of the ASSASS.

In spite of the similarities discussed above and outlined in Table 11, it is important to note that the US-ASSASS demonstrated greater fidelity to the underlying TRAPB theoretical framework compared to the ASSASS. This is evident by the grouping of all items included in the final version of the instrument into sub-scales as predicted during the instrument development process. It is equally important to highlight that all of the sub-scales predicted from the TRAPB framework were identified and retained during CFA. In the Arabic version, by comparison, there were instances whereby items clustered in ways that varied slightly from the intended constructs, albeit in interpretable ways, and gave rise to sub-scales other than those predicted.

Descriptive Statistics

Descriptive statistics were computed using the Illinois student responses to the US-ASSASS. The first step in this process was to look for the existence of any patterns, keeping in mind those outlined in the research literature. Table 12 presents students' mean factor scores, across all grade levels, disaggregated by community type. A consistent pattern, involving one community type with noticeably higher mean scores across multiple factors, was not identified. While the suburban community type does hold the highest mean factor scores in four of the five sub-scales, excluding the attitude factor, the lead over the other community types is minimal. Similarly, despite having the highest mean attitude score, the difference of city did not achieve statistical significance when compared to the other community types with one-way analysis of variance ($p = 0.068$).

Table 12

Mean Factor Scores by Community Type

			Factor									
	Respondents		Attitude		Intention		Behavior		Control		Normative	
Community	*n*	%	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
City	151	10.5	3.64	0.87	2.97	0.82	3.64	0.49	3.71	0.71	2.74	0.92
Suburban	344	23.9	3.48	0.94	3.03	0.97	3.71	0.48	3.73	0.74	2.74	0.96
Town	328	22.7	3.41	1.06	2.99	0.94	3.66	0.57	3.66	0.87	2.68	0.90
Rural	619	42.9	3.41	1.05	2.86	0.89	3.59	0.56	3.70	0.80	2.60	0.90

To explore changes in students' responses to the US-ASSASS across the grade levels examined, mean factor scores were computed and compared for each grade level. Table 13 shows that students' mean intention, behavior, and normal factors scores all, generally, increase across grades 5 through 12. For the intention factor, in particular, the extension to grades 11 and 12 was notable because mean scores among upper secondary students seemed to spike. Deviations observed in responses from upper secondary students, grades 11 and 12, are documented throughout this section and ultimately contributed to the decision to limit my analytical focus to those students presumed to be completing compulsory science in grades 5 through 10.

Table 13

Mean Factor Scores by Grade Level

Students		Factor									
		Attitude		Intention		Behavior		Control		Normative	
Grade	*N*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
5	286	3.74	0.96	2.88	0.81	3.59	0.52	3.83	0.68	2.56	0.83
6	215	3.60	0.95	2.92	0.76	3.69	0.48	3.89	0.69	2.66	0.88
7	162	3.40	1.01	2.90	0.96	3.64	0.56	3.76	0.82	2.76	0.97
8	243	3.36	0.97	2.89	0.90	3.61	0.51	3.70	0.75	2.63	0.96
9	254	3.27	1.06	2.94	0.99	3.59	0.58	3.51	0.90	2.61	0.90
10	131	3.20	0.99	2.99	0.93	3.62	0.56	3.35	0.85	2.74	0.87
11	73	3.24	1.03	2.99	1.06	3.76	0.56	3.63	0.81	2.81	1.02
12	78	3.65	1.05	3.35	1.12	3.89	0.54	3.86	0.79	2.90	1.05

The mean scores for the aforementioned factors, across grades 5 through 12, is depicted visually in Figure 7. Note also, among the three factors whose mean factor scores generally increased with grade level, that the behavior factor had the highest mean factor score throughout. On a Likert scale with positive and negative ends of the spectrum separated by a score of 3, the mean scores on the behavior factor were consistently positive, intention was much closer to the midpoint, and the normative factor scores were below 3 throughout. These results show that participants' responses to these three factors remained relatively stable through early secondary school. Participants in late secondary school, who likely completed the US-ASSASS in an elective science course, reported noticeably greater intentions for engaging in science in the future. Students who persisted in science until late secondary school also yielded more positive responses for the behavior and normative factors.

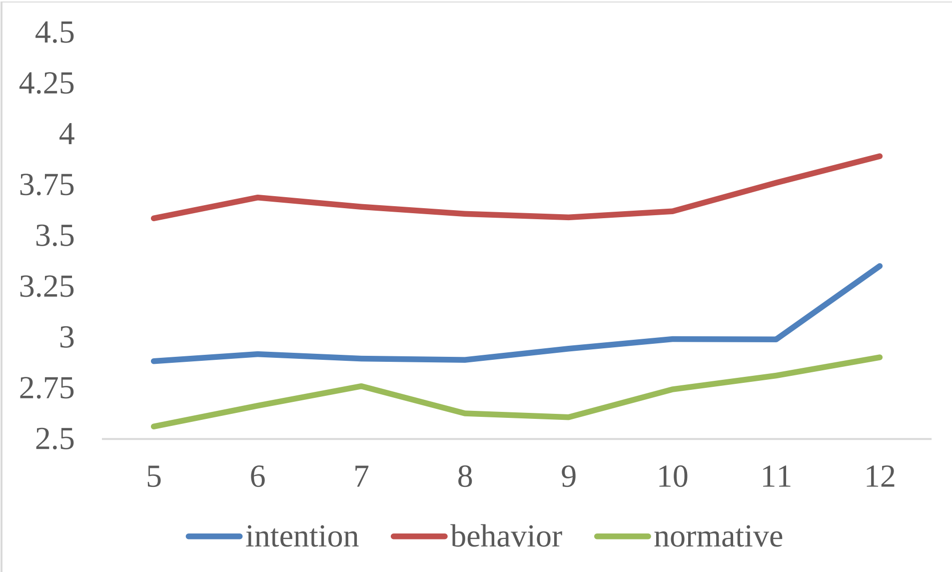


Figure 7. Students' mean scores on intention, behavior, and normative factors by grade level

In comparison to the aforementioned factors, students' mean scores appear to, generally, decline with grade level from grades 5 through 10 on the attitude and control factors (Table 13). For the attitude factor the change in mean score was more than half a point (.54 point) on the Likert scale when comparing students' responses in grades 5 and 10. Mean scores for the control factor remained higher than the attitude factor throughout, and it is important to note that mean scores for both factors remained above 3 across all grade levels. The difference between grades 5 and 10 on the control factor were slightly more severe (0.62 point). These negative trajectories; however, did not continue through grades 11 and 12 on the attitude and control factors. Instead from upper secondary students' responses, as presented in Figure 8, the mean scores on both factors increased. The sudden change in direction, to a positive trajectory, for grades 10 and 12 on the mean attitude and control factor scores could be the self-selection of these students into Advanced Placement and/or Honors science courses in grades 11 and 12. Students may also elect to take additional courses in science beyond the common high school requirements in Illinois. These students, in grades 11 and 12, may hold more favorable views toward science than other students of the same age. In either case, it is likely that students in the latter two grades are not representative of all students in these grades levels.

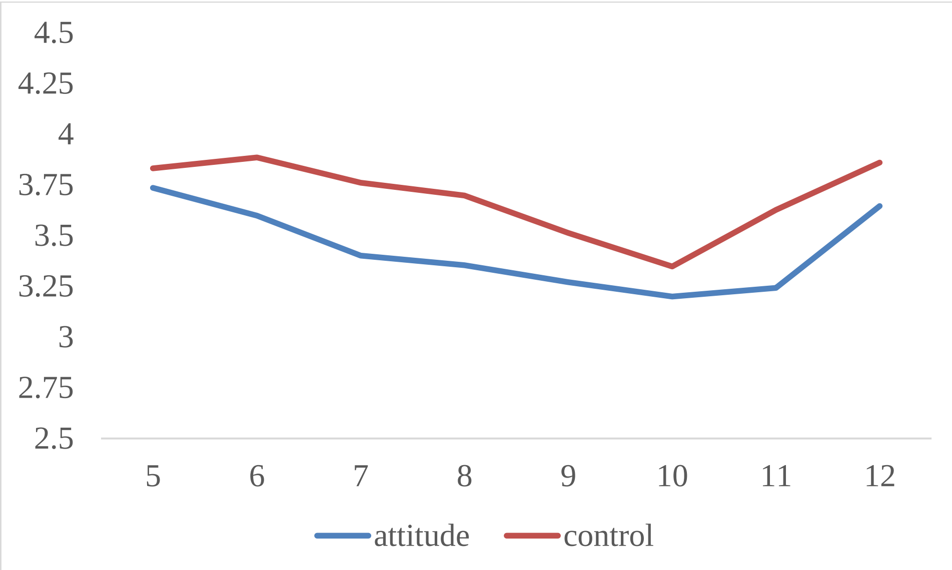


Figure 8. Students' mean scores on attitude and control factors by grade level.

To further investigate any patterns in the mean factor scores of the five factors on the US-ASSASS across grades 5 through 12, these scores were disaggregated based on student gender. This information, for students who provided their gender, is presented in Table 14. The mean factor scores in Table 14 follow the same general pattern as those presented previously in Table 13; however, the attitude, intention, and control factors revealed interesting patterns when examined by gender. In the case of the attitudes toward science factor, Table 14 highlights that male students reported more favorably, in general, across grades 5 through 10. At grade 10 there was a difference of 0.29 point between the mean scores of males and females. Students in upper secondary school deviated from this pattern, and females in grade 12 reported more favorable attitudes compared to their male peers.

Table 14

Mean Factor Scores by Gender and Grade Level

	Students			Factor																			
		Females	Males	Attitude				Intention				Behavior				Control				Normative			
Grade	*N*	*n*	*n*	$\bar{F}$	*SD*	$\bar{M}$	*SD*	$\bar{F}$	*SD*	$\bar{M}$	*SD*	$\bar{F}$	*SD*	$\bar{M}$	*SD*	$\bar{F}$	*SD*	$\bar{M}$	*SD*	$\bar{F}$	*SD*	$\bar{M}$	*SD*
5	286	150	133	3.74	0.95	3.72	0.98	2.86	0.78	2.89	0.84	3.60	0.45	3.57	0.59	3.82	0.62	3.83	0.73	2.63	0.80	2.47	0.87
6	215	113	101	3.57	0.97	3.61	0.94	2.93	0.83	2.90	0.67	3.71	0.51	3.67	0.46	3.86	0.68	3.92	0.71	2.78	0.87	2.53	0.88
7	162	78	84	3.25	1.06	3.54	0.94	2.76	0.89	3.02	1.00	3.59	0.55	3.70	0.57	3.62	0.87	3.89	0.76	2.65	0.97	2.87	0.97
8	243	109	132	3.30	0.95	3.41	0.98	2.84	0.95	2.94	0.86	3.61	0.46	3.60	0.55	3.66	0.81	3.73	0.70	2.58	0.93	2.67	1.00
9	254	112	111	3.21	1.05	3.28	1.13	3.06	0.97	2.86	1.06	3.63	0.55	3.56	0.64	3.41	0.92	3.56	0.92	2.65	0.94	2.58	0.90
10	131	68	62	3.06	0.98	3.35	1.00	2.85	0.94	3.15	0.92	3.60	0.50	3.64	0.62	3.20	0.84	3.50	0.84	2.72	0.91	2.77	0.84
11	73	45	27	3.15	1.04	3.49	0.91	2.99	1.12	3.01	0.99	3.77	0.50	3.84	0.48	3.50	0.78	3.88	0.79	2.88	1.04	2.77	0.96
12	78	49	28	3.81	0.92	3.36	1.22	3.46	1.17	3.16	1.03	4.02	0.34	3.67	0.72	3.88	0.70	3.82	0.93	3.02	0.98	2.70	1.17

Note. Gender was not reported by all students.

Figure 9 illustrates the multiple fluctuations, hovering around the midpoint, observed in students' mean scores on the intention factor. Note that grade 10 males' mean intention scores are higher than students in grade 5, but this is not the case for females in the sample. Only female students in upper secondary school have a higher mean intention scores than those in grade 5, with scores that continue to increase between grades 11 and 12 with a comparative scale difference of 0.60 point. These findings suggest that girls who opted to take science in grades 11 and 12 appear to have higher intentions to pursue or engage with science in the future compared to their male counterparts. It is important to recognize that this finding may mask some other attribute (e.g., achievement motivation) and is limited to the comparison of students who, likely, elect to take science courses in upper secondary school. However, overall, the descriptive statistics reported from this study indicate a very different image of gender discrepancies with regard to students' attitudes toward science compared to both research (e.g., Keeves & Kotte, 1992) and policy documents (e.g., National Academies, 2006).

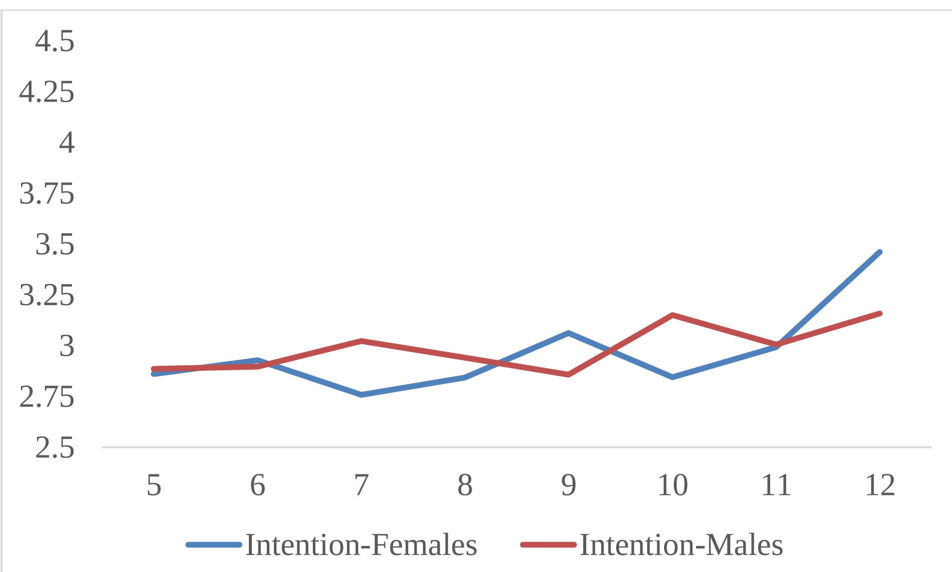


Figure 9. Comparison of mean intention factor scores by grade level and gender.

Figure 10 highlights a difference in magnitude whereby males reported, on average, higher scores on the control factor compared to females. Both male and female students' mean scores on the control factor follow a similar pattern of generally declining across grades 5 through 10. It is important to underline that this apparent difference is not consistent across all grade levels.

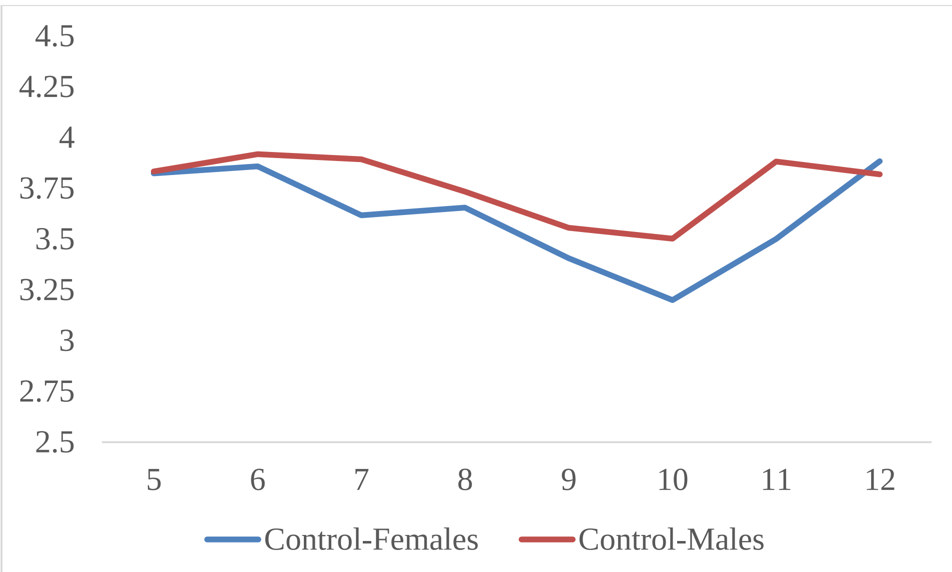


Figure 10. Comparison of mean control factor scores by grade level and gender

Inferential Statistics

Exploratory analysis. Various exploratory analyses were conducted in order to arrive at preliminary mixed models for each of the factors on the US-ASSASS. The first step in this process was to select a random sub-sample of schools. This set of responses was used to graphically explore patterns in students' mean scores on each of the five sub-scales and on predictor variables obtained from students' responses to demographic items. Table 15 provides a description of the notable student-level predictor variables examined.

Table 15

Predictor Variables From the US-ASSASS Used to Explore Content Item Responses

Variable	Description	Type
Grade level	The grade level of the student.	Continuous
Gender	Gender as reported by the student.	Categorical
Ethnicity	Ethnicity as reported by the student. Students were allowed to identify with multiple ethnicities.	Categorical
Grades	Students' opinion on their performance and perceived ability in science class.	Continuous
Talk	A measure of the frequency that students' talk to a parent or guardian about school.	Continuous

The group-level information collected from the Illinois Report Card and NCES, listed in Table 7 in the previous chapter, along with variables collected from teacher responses to the Science Teacher Survey, presented below in Table 16 below, were similarly explored. In the case of the latter, a reduced dataset and a different sub-sample were used for exploratory analysis because these variables were not available for the entirety of student respondents.

Table 16

Categorical Predictor Variables Generated From Responses to the Science Teacher Survey

Variable	Description
Advanced	Denoted if the surveyed class section was classified as an advanced placement or gifted class.
Class size	Information about the total number of students in the surveyed class section provided by the teacher.
Science period	The average amount of time students received science instruction each week.
Science portion	The number of portion of the school year students receive science instruction.
Experience	Reflected the years of teaching experience the teacher possessed.
Degree type	The highest degree obtained by the teacher.
STEM degree	Identified teachers who had a STEM-related focus in their undergraduate or graduate studies.

Note. This information was not available for all participating class sections. These variables were explored with a reduced dataset.

Graphical exploration revealed that many of the predictor variables appeared to have random intercepts. Only two predictor variables, "grades" and "talk," were possible candidates for a random slope component in the model. Using information collected from the exploratory analyses, mixed models for each of the five sub-scales were computed in order to examine the significance of the predictor variables. These models were computed in SAS (PROC MIXED). Each factor, or sub-scale, was systematically tested by creating saturated models followed by the stepwise deletion of non-significant variables. Significant variables in these preliminary mixed models were noted and were revisited during the construction of the multivariate multi-level model as discussed in the following section.

Of the student-level variables considered, only the "grades" and "talk" variables were significant ($p < .001$) across all five sub-scales. Recall that these variables reflect students' perceptions of ability in science and the frequency they talk about school with someone in their family. Gender was significant on the attitude ($p < .01$) and control ($p < .001$) sub-scales. In both cases male students were estimated to score better on these factors when compared to equivalent female students. Ethnicity was significant on the control ($p = .04$) and normative ($p = .04$) sub-scales, suggesting that White students and Asian students had higher mean scores, on each respective sub-scale, compared to their peers. There was also a significant interaction between the attitude factor and students' grade level when treated as a continuous variable ($p = .02$). This interaction indicated a negative relationship whereby students' mean scores on the attitude factor decreased as they progressed through school.

Examination of the group-level variables collected from the Illinois Report card and NCES did not reveal any significant variables. From the group-level predictor variables provided by teacher responses to the Science Teacher Survey, the "advanced" and "class size" variables were significant on the behavior sub-scale (p = .05 and p = .01, respectively). It is notable that the estimate for the advanced variable is comparatively high for this factor, similar in magnitude to the grades variable mentioned above. If it were possible, the advanced variable would have been investigated more in depth, such as the comparison of regular and advanced class sections at specific grade levels, but only 9 class sections, or 171 students, reported advanced status in the sample.

It is important to note that some student- and group-level variables, were examined in multiple ways (i.e., continuous vs. categorical). Categorical variables, particularly those with multiple levels (e.g., ethnicity, with eight levels), were explored and refined in an effort to determine their statistical significance. This process involved condensing levels that behaved in similar ways. For example, only two levels within the ethnicity variable appeared to be significant on any of the five factors, Asian students on the normative factor and White students on the control factor. To ascertain whether membership into a particular racial group conferred some boon to students' estimated score for each factor, the variable was recoded and reduced down to three levels (i.e., Asian, White, and other) in an effort to quantify a possible race effect. In this case, the recoded race variable, still, did not yield a statistically significant effect. The absence of a racial effect is documented in the literature (e.g., Simpson & Oliver, 1990), with researchers instead drawing attention to more dominant individual characteristics (i.e., gender) that seemingly account for differences in students' attitudes toward science.

Multivariate multi-level modeling. Before compiling the various individual factor models into a multivariate multilevel model, it was necessary to transform the dataset. This transformation allowed individual mean factor scores, for each respondent on each of the five factors, to serve as the response variable as explained by Templin (2014). The use of mean scores, more specifically the mean of all completed items for a given factor, was important because it ensured that all respondents had data for the five factors. Multivariate multilevel model building, also done in SAS (PROC MIXED), generally proceeded by allowing one variable to vary at a time and comparing any changes to the previous model in order to assess better model fit (Raudenbush & Bryk, 2002). Informed from the exploratory analyses conducted, predictor variables and interactions that were significant on the individual factors guided the model building process. Attentive to the noticeably different patterns observed in students mean responses to each sub-scales in grades 5 through 10 compared to grades 11 and 12 in the descriptive analysis, it was decided that only the data collected from students in grades 5 through 10 would be used to compute the multivariate multilevel model and reported in the subsequent final model.

Table 17 summarizes major models considered during the building process, which began with the construction of the empty, or null, random intercept model (Model A). The five factors, which were grounded in the underlying TRAPB framework were added (Model B). Next the interactions for the “talk” and “grades” variables were added for each of the five factors (Model C), a decision based on the influence of these variables on multiple factors. Model D attempted to better account for the interactions of the grades variable by including a random slope component. Note that a random slope could have been affixed to the talk variable, recalling that the talk and grades variables were both identified in exploratory analyses. However, adding random slopes for both variables to the model was harmful to fit, as judged by the fitness criteria (i.e., lower values for -2Log Likelihood, AIC, and BIC). The model with a random slope for grades was advanced because it appeared to fit better than the alternative random slope.

Table 17

Comparison of Notable Multivariate Multi-Level Models

Model	Components	Parameters	-2Log Likelihood	AIC	BIC
A	*Null* Random Intercept	15	17635.3	17665.3	17742.7
B	*Five Factor* Random Intercept Attitude Intention Behavior Control Normative	15	12581.2	12611.2	12688.7
C	*Five Factor with Talk and Grades interactions* Random Intercept Five Factors, Talk*Five Factors, and Grades*Five Factors	15	11715.2	11745.3	11822.3
D	*Model C with Random Slope* Random Intercept Random Slope (Grades) Five Factors, Talk*Five Factors, and Grades*Five Factors	16	11797.4	11829.4	11864.7
E	*Model D with Gender Interactions* Random Intercept Random Slope (Grades) Five Factors, Talk*Five Factors, Grades*Five Factors, Gender*Attitude, and Gender*Control	16	11646.3	11678.3	11713.5
F	*Model E with Ethnicity Interactions* Random Intercept Random Slope (Grades) Five Factors, Talk*Five Factors, Grades*Five Factors, Gender*Attitude, Gender*Control, Ethicity*Control, Ethnicity*Normal	16	11656.4	11688.4	11723.6

(continued)

Table 17 (continued)

Model	Components	Parameters	-2Log Likelihood	AIC	BIC
G	*Model E with Grade Level (Linear) on Attitude and Control* Random Intercept Random Slope (Grades) Five Factors, Talk*Five Factors, Grades*Five Factors, Gender*Attitude, Gender*Control, Grade Level*Attitude, Grade Level*Control	16	11536.4	11572.4	11612.1
H	*Model G minus Random Slope* Random Intercept Five Factors Talk*Five Factors Grades*Five Factors Grade Level*Attitude Grade Level*Control Gender*Attitude Gender*Control	15	11593.0	11623.0	11699.9

The next set of models (Models E, F, and G) examined interactions with variables on one or more factors, but these interactions differed from the previous set as they were not expected on all factors. Model E included gender interactions on the attitude and control beliefs factors, which improved model fit. Model F attempted to also include race into the model, focusing on the control and normative factor interactions suggested by exploratory analysis. Some racial groups, as indicated by specific levels of the racial variable, appeared to benefit on the control and normative factors. However, the inclusion of these interactions did not improve model fit and attempts to recode the categorical race variable in a meaningful way were unsuccessful. The interactions with the race variable were ultimately omitted because their addition did not significantly improve model fit as determined by a log likelihood ratio test ($p = 0.44$). Model G included an interaction between the attitude factor and grade level. The inclusion of the grade level interaction, when treated as continuous variable, significantly improved model fit ($p < 0.001$).

The final steps in this process involved reevaluating all of the components added to the model to ensure that all remained significant. During this process it was determined that the random slope for the grades variable, which had been added early in the building process, was no longer needed because its deletion did not significantly harm model fit (p = 0.001). Model H represents the final multivariate multilevel model derived using the entire analytic sample of US-ASSASS respondents. All variables retained in the final model were statistically significant to the $p < 0.001$ level, with the only exception being the gender interaction on the attitude factor (p = 0.02).

Representations of the final model. Note that the final model contains only Level 1 (within-group) predictor variables. The naming conventions denote each of the five factors in the equation, along with the interactions specified for Model H in Table 17 (above). No overall intercept was reported, coded in SAS using the NOINT option.

$$Y_{ij} = \beta_{0j}^{ATT} D_{0j}^{ATT} + \beta_{0j}^{INT} D_{0j}^{INT} + \beta_{0j}^{BEH} D_{0j}^{BEH} + \beta_{0j}^{CON} D_{0j}^{CON} + \beta_{0j}^{NOR} D_{0j}^{NOR} + \beta_{0j}^{ATT} (grade\ level)_{0j}$$

$$+ \beta_{0j}^{ATT} (gender)_{0j} + \beta_{0j}^{CON} (grade\ level)_{0j} + \beta_{0j}^{CON} (gender)_{0j} + \beta_{0j}^{ATT} (talk)_{0j}$$

$$+ \beta_{0j}^{INT} (talk)_{0j} + \beta_{0j}^{BEH} (talk)_{0j} + \beta_{0j}^{CON} (talk)_{0j} + \beta_{0j}^{NOR} (talk)_{0j} + \beta_{0j}^{ATT} (grades)_{0j}$$

$$+ \beta_{0j}^{INT} (grades)_{0j} + \beta_{0j}^{BEH} (grades)_{0j} + \beta_{0j}^{CON} (grades)_{0j} + \beta_{0j}^{NOR} (grades)_{0j} + R_{ij}$$

$$\beta_{0j}^{ATT} = \gamma_{00}^{ATT} + U_{0j}^{ATT}$$

$$\beta_{0j}^{INT} = \gamma_{00}^{INT} + U_{0j}^{INT}$$

$$\beta_{0j}^{BEH} = \gamma_{00}^{BEH} + U_{0j}^{BEH}$$

$$\beta_{0j}^{CON} = \gamma_{00}^{CON} + U_{0j}^{CON}$$

$$\beta_{0j}^{NOR} = \gamma_{00}^{NOR} + U_{0j}^{NOR}$$

Interpretations of the final model. Table 18 presents the estimates for all of the significant effects in the final model organized by sub-scale. The final model would suggest that an average male in fifth grade would have a base score of 3.18 on the attitude factor, 2.06 on the intention factor, 2.96 on the behavioral beliefs factor, 2.91 on the control factor, and 1.74 on the normative factor. Students' estimated base scores, on all five factors, may be increased depending on their perceived ability in science and the frequency they talk with family members, as gauged by self-report.

Table 18

Significant Effects From the Final Model

Effect	Estimate	Standard Error	*p*-value
Attitude	3.18	0.13	<.001
Attitude*gender (female)	-0.08	0.04	0.02
Attitude*grade	-0.11	0.01	<.001
Attitude*grades	0.25	0.02	<.001
Attitude*talk	0.09	0.02	<.001
Intention	2.06	0.08	<.001
Intention*talk	0.08	0.02	<.001
Intention*grades	0.18	0.02	<.001
Behavior	2.96	0.05	<.001
Behavior*talk	0.07	0.01	<.001
Behavior*grades	0.13	0.01	<.001
Control	2.91	0.10	<.001
Control*grade	-0.07	0.01	<.001
Control*gender (female)	-0.13	0.03	<.001
Control*grades	0.36	0.02	<.001
Control*talk	0.06	0.01	<.001
Normative	1.74	0.08	<.001
Normative*talk	0.15	0.02	<.001
Normative*grades	0.13	0.02	<.001

All other variables equal, a female in fifth grade would be expected, on average, to score comparatively to their male counterparts on all factors except attitude and control. The gender interaction in the model estimated that girls' base score on the attitude factor is 0.08 points less, and 0.12 points less on the control factor compared to boys in the same grade. As a result, a comparative female student would instead be expected to score a 3.10 on the attitude factor and a 2.79 on the control factor. The relative severity of these effects are further discussed in the next section.

According to the final model, grade level also impacts the attitude and control factors for all students. Everything else being equal, boys in fifth grade would be expected to obtain a base score of 3.18 on the attitude factor. For each 1-point increase in grade level, beyond grade 5, students are expected to decrease their score on the attitude factor by 0.11 of a point. All other variables held constant, to compare with the reference score of a fifth grade boy, a similar boy by grade 10 would be expected to have their attitude score reduced by more than half a point (0.55) on the 5-point scale. Likewise, the same 1-point increase in grade level is predicted to decrease boys' scores on the control factor by 0.07 of a point. This grade level interaction would predict that by grade 10 a male student would have lost 0.35 of a point on their control factor score when compared to a similar student in grade 5 and all other variables are held constant. Lastly, it is important to recognize that the grade level interactions on the attitude and control factors are predicted to be more pronounced for girls because of gender effects on those same factors. When coupled together, without considering any mediating variables, a girl in grade 10 could fall 0.63 of a point below the base score on the attitude factor (2.55) and 0.48 of a point below the base score on the control factor (2.43).

As mentioned previously, there were two variables that interacted positively with all factors and were included in the final model. The first of these variables, referred to previously as grades, estimated that, on average, students who reported a 1-point increase in perceived science ability increased their attitude score by 0.25, intention by 0.18 behavioral beliefs by 0.13, control beliefs by 0.36, and normative beliefs by 0.13. The talk variable, the second variable that appeared to bolster all factors, indicates that students' who reported a 1-point increase in the frequency they talked with their parents increased their attitude score by 0.09, intention by 0.08, behavioral beliefs by 0.07, control beliefs by 0.06, and normative beliefs by 0.15. To put the importance of these variables in perspective, consider that students who perceive themselves to be highly capable in science and who also talk with their family in high frequency about science would be expected to increase all their factor scores by at least 1-point, at any given instance that these conditions were met, according to the final model.

Effect size of the interactions included in the final model. The final model included interactions between the attitudes and control beliefs factors with gender, indicating that male students are favored slightly over females with a higher base scores on these two factors assuming everything else is equal. These discrepancies were also observed during descriptive analysis (Table 14). Questions included in the attitude factor (previously listed in Table 9) converge on topics associated with school science and science learning (e.g., I really enjoy science lessons). The control beliefs factor addresses issues surrounding students' attitudes about their ability to excel in class (e.g., "I am confident that I can understand science"). Effect size, Cohen's *d*, was computed using the mean scores for males and females on both factors. Comparison of male and female mean scores on the attitude factor, from students in grades 5 through 10, revealed a very small effect size ($d = 0.13$). The effect size of the gender difference on the control beliefs factor was determined to be very small ($d = .18$) as well. It should be noted that, for the social sciences, Cohen (1992) defines an effect size of 0.2 as small, 0.5 as moderate, and 0.8 as large when using Cohen's *d* as the index. An effect of this size suggests that while the gender effect detected and included in the final model has statistical significance, it may not be practically meaningful.

The final model also accounted for the pattern observed in students' scores on the attitude and control beliefs factors where, in general, students' scores decreased as grade level increased. To better understand the impact of the interaction between a students' score on the attitude factor and grade level effect size was computed, revealing a small effect for individual grade levels (*d* values ranging 0.04-0.15). Alternatively, the influence of grade level may be better portrayed by examining the cumulative difference in students' mean scores on the attitude factor between grades 5 and 10, which resulted in a moderate effect ($d = 0.55$). Examined in the same way, grade level was found to have a moderate effect ($d = 0.63$) on the control beliefs factor.

Chapter V

Discussion

The present study explored precollege students' attitudes toward science and their intentions regarding the continued study of science in the future. The guiding research questions were: "What is the landscape of Illinois students' attitudes toward science across their school experience?" and "To what extent do school characteristics, including the attributes of classroom teachers, influence student attitudes toward science across the state of Illinois?" This chapter attempts to explain the patterns identified in students' responses to the US-ASSASS. The chapter also unpacks the impact of other variables explored over the course of the study, which pertain to the learning environment, such as teacher and school characteristics.

Illinois students' responses to the US-ASSASS revealed that the items comprising the instrument clustered around factors or sub-scales that reflected the core constructs of the TRAPB TRAPB, which guided the instrument development. The finalized instrument sub-scales were: attitudes toward science, intention, behavioral beliefs, control beliefs, and normative beliefs. Descriptive statistics revealed that, in general, the mean scores on the intention, behavioral beliefs, and normative beliefs sub-scales increased with grade level. In contrast, students' mean scores on the attitude and control beliefs sub-scales generally decreased with grade level through grade 10. Collectively, the patterns observed in student responses raise two important questions. The first is what concerns should educators, policy makers, and researchers have about the consequences of the negative trends observed? The second question, inspired by Ramsden's (1998) depiction of the overarching goal for research in this area, asks what factors might help to create a climate that best helps young people develop positive dispositions toward science?

Historically, the impact of attitudes on student learning (Lester, Garofalo, & Kroll, 1989; Shaughnessy, Shaughnessy, & Haladyna, 1983) and their continued interest in a subject (Eccless, Wigfield, Harold, & Blumenfeld, 1993) has been sufficient to deem the development of positive attitudes important by researchers. It has been suggested that declining attitudes toward school subjects over time is a phenomenon that seems to apply to various topics (Sutcliffe, 1998), and is specific to science. However, there is limited empirical evidence to support this claim. Among researchers focused on science education, the decline in students' attitudes has been well documented (Farenga & Joyce, 1998; Kelly, 1986; Pell & Jarvis, 2001; Speering & Rennie, 1996). Findings from the present study align with previous research to affirm a negative interaction between grade level and students' reported attitudes toward science. This decline was evident in participant responses, in grades 5 through 10, as corroborated by a significant effect in the final multivariate multi-level model. While some students obviously persist and continue to take science courses beyond the number required in high school, or elect to even take advanced science courses, it is unclear the role students' eroding attitudes toward science play in their later decisions to pursue additional coursework, or science-related careers. Extant research employing the TRAPB framework is limited (e.g., Koballa, 1988b), but does suggest that attitude toward a behavior, such as enrolling in an elective science course, is a strong predictor of the target behavior. Koballa (1990) also noted that individual student characteristics and ability have an impact on the degree to which attitude can act as a predictor.

Influence of Individual Characteristics on Measured Constructs

Gender. One particularly encouraging finding from the present study with regard to the characteristics of individual respondents was that there were few gender-based differences identified in student responses. Consistent with prior research (Jones, Howe, & Rua, 1998), this study found that both genders express a decrease in their attitudes toward science as they advance through school. The final multivariate multi-level model revealed gender effects on two of the five instrument sub-scales. This interaction in the final model suggested that, everything else being equal, male students, on average, will score higher than their female counterparts on the attitudes toward science and control beliefs sub-scales. Of course, any discriminatory effect on students' self-confidence and ability to understand science concepts is cause for concern, especially if such an effect would discourage females from continued engagement in science. Nonetheless, compared to some extant literature, the gender effect detected in this study is quite small. Indeed, the present results conflict with earlier studies, which heralded gender as the most influential individual characteristic (Greenfield, 1997; Schibeci, 1984) and contended that female students experienced a strikingly severe decrease in their attitudes toward science, over time, compared to males (Kotte, 1992).

A body of literature exists that draws attention to gender-based discrepancies with regard to students' progression through the science pipeline spanning from reported attitudes and interests, and extending to the completion of advanced degrees and pursuit of science related careers. The American Association of University Women Report (1991), which is perhaps the best known progenitor of this rhetoric, proclaimed that America is being shortchanged by failing to interest more females in mathematics and science. Researchers added to these concerns by highlighting that students' attitudes toward science, and the differences therein, lead to differential course enrollment (Harpole, 1987; Tippins, 1991), lower female science achievement scores (McNeil & Butts, 1981) and fewer females in science related careers (Kahle, 1984; Moffat, 1992). Indeed, *Beyond Bias and Barriers* (National Academies, 2006) reported a gender gap in the number of PhDs earned in STEM-related fields as of 2003. Collectively, these allegations of a “leaky” pipeline have drawn the attention of educators, researchers, and policy makers to differential outcomes in science, and related careers, on the basis of gender.

Indeed, differences do exist in the progression of males and females through the science pipeline as the previously referenced reports suggest, but there has been noticeable progress since the 1991 report (American Association of University Women, 1991). In fact, since 1994 the gender gap in science and mathematics courses has narrowed and the number of females placed in advanced chemistry and biology courses has been higher than males (National Academies, 2006). In this study, there was no gender effect included in the final model for the intention sub-scale, which deals with students’ intentions to continue studying science and pursue careers in science. The present findings show that, on average, boys and girls have similar intentions toward science when all else is equal. Moreover, the findings showed that girls in grades 11 and 12 who persisted in science had higher average scores on the intention sub-scale compared to their male counterparts.

The present findings are better understood by examining the relationships between the various constructs of interest. Oliver and Simpson (1988) claimed that a strong relationship exists between students’ attitude towards science, motivation to achieve, and their self-concept about their ability to achieve in science. A similar relationship presumed by the underlying theoretical framework, the TRAPB, suggests that students’ intentions are influenced by their attitudes and control beliefs. The present results suggest that females have a high motivation to achieve academically or are determined to pursue science in spite of their slightly lower predicted scores on the attitudes toward science and control beliefs sub-scales. These relationships surely deserve to be investigated in a more controlled manner to examine, in greater detail, the underlying reasons behind these patterns in participant students’ responses.

There is another important consideration related to understanding and interpreting the role of gender in student attitudes toward science; namely, an underlying assumption that may obscure interpretation of the current situation and perceived inequities in the science pipeline. The aforementioned literature focuses on barriers that stymie the progress of females in science always in comparison to their male counterparts, whose attitudes and pathways are set as the default standards. An alternative interpretation, which has been gaining more attention and followers (see Baker & Leary, 1995), derives from consulting feminist paradigms when interpreting students' preferences about science. The latter perspectives encourage researchers to avoid a deficit model, or the assumption that male behavior is the norm, in an effort to independently understand women's socio-psychological reality as expressed in educational preferences, needs, and goals (Campbell, 1988). Viewed from this perspective, the present findings support the absence of a "negative" pattern in connection to female participants, in the sense that observed differences in their control beliefs related to confidence of performing well in science may be rooted in other personal traits (e.g., modesty). This shift in thinking would draw attention back to the central issue of improving students' attitudes toward science, along with their beliefs about the benefit of science and their ability to understand science, in an ultimate effort to retain *all* students as lifelong learners of science.

Student-parent interaction. Of all the individual student characteristics considered in this study, there were two that stood out, impacting students' scores on all five sub-scales of the US-ASSASS. The first, previously denoted as "talk," referred to the frequency a student talked with someone in their family about school. The present results suggest that students who talked more frequent with a family member about school scored higher on all sub-scales. The connection between parent involvement and student achievement is well established (e.g., Henderson & Berla, 1994; Thorkildsen & Stein, 1998). Among the various types of parenting practices and behaviors that have been associated with positive student outcomes, researchers highlight the importance of parents' participation in school events or activities, parental assistance at home, and participation in and discussion about learning activities (Stevenson & Baker, 1987; Eccles & Harold, 1993). In general, researchers have suggested that parents who take an interest in their child's schooling can help foster positive attitudes about the importance of school success (Hoover-Dempsey, Bassler & Burow, 1995). While the literature makes some mention of parental influence in relation to students' attitudes toward science (e.g., Morrell & Lederman, 1998), the influence of parent-child talk appears to be understudied in science education research employing the TRAPB framework. Early assertions pertaining to parental interactions, such as those made by Koballa and Crawley (1985), focused on the transmission of attitudes and beliefs from parent to child (i.e., parent does not see the importance of science and this negative attitude is transmitted to the child). Instead, given the present results and the significant impact of parent-child talk on Illinois student responses, it might be better to consult an alternate perspective that aligns more closely with modern theoretical perspectives. Coleman and colleagues (e.g., Coleman, 1987, 1988, 1991; Coleman & Hoffer, 1987) contended that parents' involvement in their child's schooling, including parent-child discussions about school, creates additional sources of social constraint to influence the child's behavior. If this contention holds, it is plausible that the perceived pressure (which is probably better characterized as care) created by parents, akin to the "subjective" dimension that the TRAPB aims to assess, may influence multiple constructs instead of isolating parental influence to the normative TRAPB construct.

Perceived ability in science. A second variable that was most impactful in characterizing students' responses to the US-ASSASS, previously denoted as "grades," referred to students' beliefs regarding their performance in science. The present findings suggest that students who had a higher perceived ability in science scored higher on all sub-scales. Oates, Gunstone, Nortfield, and Fensham (1980) indicated that affect and achievement reinforce each other, and that students' attitudes and achievement have an interactive relationship. In other words, a student's current enjoyment and enthusiasm for science is, and will be, determined by that student's perceptions of his/her past science performance. Students who do well in science generally have more positive attitudes towards the subject, and those who have more positive attitudes tend to perform better (Beaton et al., 1996). Given the present results, it is interesting to think about students' perceived ability in science and the extent that science teachers contribute to this perception. Judgments and feedback provided by teachers influence their students' expectations of future science performance and also their perceived usefulness of science at school and beyond (Martin, 1996).

Influence of Teachers and Schools on Attitudes toward Science

Teacher characteristics. It has been thought for some time that teacher's attitudes toward science influence their students' attitudes (Washton, 1971; Morrell & Lederman, 1998). Fishbein and Ajzen (1975) noted that the science teacher, a figure of significance for students, and situational variables under their control set the context for science learning, and therefore determine the consistency between attitude and behavior in students. Researchers, such as Martin (1996), contend that teachers who had the greatest positive effect on students' attitudes and achievement in science were those with the most experience, scientific training, and interest in science. Using data collected from the participant teachers on the Science Teacher Survey, this study investigated a variety of classroom and teacher characteristics for possible relationships with student responses on any of the US-ASSASS five sub-scales. These variables encompassed: class size, science instruction time, and teacher training and experience. Participant Illinois science teachers' experience, degree type, and degree area(s) varied considerably. However, this variation did not help explain observed patterns in student responses. Other group-level teacher variables, such as teachers' self-reported attitudes toward science and personal interest in science, were less informative due to the uniformity in their responses.

An alternative way to gauge teachers' commitment and attitude toward science, as suggested by Purkey and Smith (1983) is to examine the time participant teachers spend teaching science (e.g., in elementary classrooms) and/or the manner in which it is taught. It is generally accepted that the amount of instructional time in science varies, especially at the elementary level. Through the late 1980s and 1990s, time spent on both science and mathematics had been increasing until shortly before passage of the No Child Left Behind Act in 2001, now titled the Education and Secondary Education Act. Since then, instructional time for mathematics has increased modestly and held steady, time for English language arts has increased substantially, while time for science has dropped to an average of 2.3 hours per week, the lowest level since 1988 (Blank, 2013). In this study, 26 of the 41 (63.4%) elementary teachers who completed the Science Teacher Survey reported that students in their class received 3-4.9 hours of science instruction every week for the entire school year. An additional 12 elementary teachers (29.3%) indicated that their students received 1-2.9 hours of science instruction every week. The remaining three elementary teachers indicated that they either taught science all year long, but for less than an hour every week, or they only offered science instruction for a fraction of the school year. Given that nearly all of the elementary teachers surveyed (92.7%) reported teaching science every week during the school year, it should come as little surprise that the subtle variation in the instructional time afforded, either 1-2.9 or 3-4.9 hours per week, did not explain much of the variance in students' US-ASSASS responses. Moreover, the few teachers who reported sporadic science instruction, that is instruction that was not consistent throughout the school year, represented too small fraction of respondents to allow detecting a related effect.

On their surface, the present results suggest that science teachers have little bearing on students' attitudes toward science. However, it is equally likely that the Science Teacher Survey employed in this study did not adequately capture other features or practices of the participant teacher, which could potentially contribute to students' positive attitudes. Fishbein and Ajzen (1975) highlighted certain elements that may help to explain the complex role that teachers play in fostering students' attitudes toward science, noting teacher-student interactions and the classroom environment as examples. Thus, there surely is need to capture and study the impact on student attitudes toward science of intensive factors, such as quality of science teachers' instruction and associated student-teacher interactions, in addition or instead of extensive factors, such as time dedicated to science instruction or teachers' self-reported interest in science.

School characteristics. Just as the with the case of teacher characteristics, school characteristics compiled in the present study did not yield any significant group-level effects, and did not help to further explain differences in students' attitudes toward science. Of the school variables examined, one striking finding was the insignificance of mean teacher salary as a group-level predictor. There was wide variance in terms of mean teacher salaries across the participant schools, with meager earnings in some areas, such as southern Illinois (mean district salary of 49,570; *SD* = 6,462), [14] compared to much more affluent schools in the Chicago

[14] Southern Illinois is represented by regions 5 and 6, from the regions depicted in Chapter 3, for the present study.

Suburbs (*M* = 70,947; *SD* = 17,979). Geographic location (i.e., rural, town suburban, and city), by the same token, did not help account for differences in students' responses.

One quite clear message from this study is that individual characteristics seem to be more effective than group-level variables in explaining differences in Illinois students' attitudes toward science and related factors. These results, which included Illinois students and teachers aggregated in schools across the state, show that students hold relatively similar attitudes toward science, and related factors, regardless of their science teacher or school. Anecdotally, of course, a particular science teacher can have a tremendous impact on students' interest and enthusiasm in science (e.g., Maltese & Tai, 2010). Similarly, it would be naïve to think that differences do not exist at the school-level with respect to science instruction, be it in terms of instructional quality or variety or science offerings, or other related facets. However, when examining data from this perspective, a statewide view encompassing grades 5 through 12 from numerous schools, the results of this study underscore the influence of individual perceptions and familial interactions whereas the extent to which the teacher and school help to shape students' attitudes toward science are unclear from this eagle eye view.

Limitations

The major limitations of the present study relate to the sample and participants. The process of recruiting participant classrooms began with the random selection of schools from within the six geographical sampling regions determined, by county, in Illinois. Following random selection, participation relied on initial contact with, and approval from, a school administrator. Teachers and administrators were asked to complete the survey for a specified grade level, but they were given the flexibility to select the participating class. By the time approvals were secured and data were collected from the 78 participant schools, 54 other schools declined participation outright, 121 schools did not respond to the invitation to participate, and 18 schools that initially agreed to participate did not follow through. With respect to the sample obtained, it is important to reiterate that schools were selected randomly, and that declining or non-responsive schools were removed from the selection pool. This is to say that thought this process every effort was made to acquire a random sample of participants, which adhered to the established systematic selection guidelines.

The composition of the sample obtained in this study was influenced by the procedures needed to gain access to schools. One major limitation was the exclusion of Chicago Public Schools (CPS) from the sample. Like many large, urban school districts, which often are inundated and overwhelmed by invitations to participate in research studies, CPS had a number of additional requirements for participation that could not be negotiated and navigated given the resources available and the scale of the present study. As a result, CPS students and teachers did not partake in the study, which substantially impacted the representativeness of the present sample. In particular, out of all 1,400 student responses, only 7.2% came from African American students (compared to 18.2% statewide), and a mere 4.8% from Hispanic students (compared to 23.6% statewide). Given the proportions of African American and Hispanic students (39.3% and 45.6% respectively) enrolled at CPS (ISBE, 2012), it was unfortunate that these schools could not be included and represented in the study.

A second limitation was that not all grade levels were represented with equivalent numbers of class sections in the final sample. This is particularly the case for grades 11 and 12, with only 7 and 3 participant class sections respectively, which fall below the targeted 12 class sections (2 from each geographical region) per grade level. There were particular difficulties associated with recruiting grade 11 and 12 classrooms to participate in the study. Administrators and teachers would often decline participation involving students in upper secondary school citing important exams (e.g., ACT) and an already tight time schedule—particularly in the case of advanced placement classes—that did not allow for non-instructional pursuits. Perhaps a better represented sample could have been obtained if secondary school students would have been sampled from a more general course (e.g., English) or if students could have been recruited from these schools at large. However, based on the overall goals of the study, the latter approach would not have been compatible because meaningful information could not have been collected from science teachers in either alternative scenario. As the study was conducted, the sampling of students from science classes worked well for grades 5 through 10. For grades 11 and 12, aside from a lower than desired number of class sections, the sampling strategy was adequate. The self-selection of students into upper level science courses, which are likely to be electives for students in grades 11 and 12, limits the generalizability of the data collected. This is reflected in the presentation of results and discussion of findings, which isolated grades 11 and 12 in many cases. Being aware of the quantity and nature of data collected from upper secondary school students led to the decision to omit these responses from the final statistical model computed.

A third limitation of the study relates to the nature of the data collected pertaining to teachers and classroom environment. Only 65 of the 78 potential participant teachers provided self-report data, collected through the Science Teacher Survey, to characterize their background as a science educator (e.g., years of teaching experience and degree area), instructional practices, and general attitude toward science. It was beyond the scope of this study to measure teachers' attitudes toward science, or characterize the quality of their classroom instruction beyond self-report. Moreover, these self-report teacher data resulted in little or no variance, which seemed to have suggested that teacher variables were not very impactful. It is not possible to ascertain claims about the importance and influence of science teachers beyond the limits of the data collected here. From the analyses conducted in this study all that can be said is that the teacher characteristics and variables compiled did not help explain variation in students' attitudes toward science and related factors.

Conclusions and Implications for Future Research

This study indicates that Illinois students' attitudes toward science decline across their K-12 experience, but it also shows that a portion of students do persist through compulsory pre-college science education and reach upper secondary school with high attitudes toward science. The decline in students' attitudes toward science with increasing grade level is consistent with extant literature, but it is important to note that the students' responses to other factors, namely the beliefs about the importance of science and students' intentions to engage in science in the future, did not deteriorate in the same manner. Admittedly, findings that suggest all students, but females more severely, have diminishing control beliefs with increasing grade level is concerning. The present results point to two important areas for future research. The first is to investigate whether the documented decline in students' attitudes is particular to science content areas, or whether it is similarly experienced by students across other core subjects (e.g., language arts, social studies). Addressing this question is important because it speaks to concerns about general dissatisfaction with the overall schooling experience that students may feel, spanning from personal (e.g., moving from childhood to adolescence) to school-specific issues (e.g., increasing content difficulty), which might underlie the documented declines of K-12 student attitudes toward science. Conducting this research might be straightforward with the most significant hurdle being the recruitment of a sizeable sample that does not favor responses toward science or the other core subject area involved, and controls for participant student experiences. One research methodology that might be helpful, to mitigate some of the difficulties that accompany longitudinal studies, is the use of an accelerated longitudinal design. Such a design, which has characteristics of both longitudinal and cross-sectional designs, would follow students from a cluster of grade levels over a shorter duration (e.g., 3-5 years) compared to traditional longitudinal approaches (see Galbraith, Bowden, & Mander, 2014).

A second significant area for research is to empirically investigate the underlying casual relationships, such as those suggested by the TRAPB framework that underlies the US-ASSASS instrument, to ensure that future research into students' attitudes toward science is guided by theory that is commensurate with the ultimate aim of fostering involvement in science. In other words, the connection between students' intention to pursue science in the future, the factors that shape their intentions, and the consistency with which these intentions predict student behavior need to be empirically examined in detail and, more importantly, empirically ascertained. While the present study did refine the US-ASSASS that is capable of assessing these causal forces in students, it was beyond the scope of this study to acquire data on *actual* students' future science behavior. To meet this need, prospective research should aim to follow groups of students as they approach key decisions related to science engagement, such as the choice to take elective coursework in science or to declare a science-related major in postsecondary school, and investigate whether prior assessments of their attitudes could predict such choices. To set this proposed research apart from the few prior attempts that have been made, it will be important to follow up with students to see if they actually fulfill their commitments to engage in science, at least to some extent. Such a study would provide insight into the consistency with which students' intention actually predict behavior, and also serve as the basis of criterion validity, or more specifically predictive validity, for the US-ASSASS instrument (see Cronbach & Meehl, 1955). Additionally, findings from this proposed research may also afford a deeper understanding of the conditions that best support the intention-behavior link with respect to making decisions related to pursuing additional science studies and potentially science careers in the future.

Findings from this study also indicate that individual variables, such as frequency of talking with family about school and perceived science ability, are better predictors of students' attitudes toward science, and associated factors, compared to other correlates (e.g., gender) that had been a focal point during the 1980s and 90s. Coupled with the null findings with respect to teacher, school, and geographic effects on students' attitudes toward science, a second important conclusion to be drawn from this study is that several assumed predictors and influences on students' attitudes may need to be reexamined. This is not to say these variables should be dismissed, instead it is important to reevaluate their possible effects in light of modern theory and assessment techniques. This reexamination needs to extend to variables associated with the teacher and school environment. It may simply be the case that complex effects, such as those resulting from the science teacher, could not be detected in a cross-sectional study and/or by a forced-choice self-report instrument. To address these concerns and advance research in this field, future efforts employing hierarchical designs, and mixed-methods approaches, within school systems would be welcome. As part of such a study, in light of the present findings, it would be meaningful to examine how teachers help shape students' perception of their ability in science and if any differences across contexts contribute to variation in students' attitudes. An alternative approach for further investigating the specific individual variables highlighted in the present study would be for educators and researchers to facilitate opportunities, imaginably through serviced-based projects, for students and their parents to engage in meaningful discourse about science, and science teaching and learning.

References

Abd-El-Khalick, F., Summers, R., Said, Z., Wang, S., & Culbertson, M. (2015). Development and large-scale validation of an instrument to assess Arabic speaking students' attitudes toward science. *International Journal of Science Education, 37*(16), 2637-2663.

ACT (2014). *The Condition of STEM 2013.* Retrieved from http://www.act.org/

Aiken, L. R., & Aiken, D. R. (1969). Recent research on attitudes concerning science. *Science Education, 53*, 295-305.

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27,* 1-52.

Aikenhead, G. S. (1997). Toward a First Nations cross-cultural science and technology curriculum. *Science Education, 81*, 217-238.

Aikenhead, G. S. (2005). *Science for everyday life: Evidence-based practice*. New York, NY: Teachers College Press.

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36,* 269-287.

Aikenhead, G. S., & Ryan, A. (1992). The development of a new instrument: "Views on Science-Technology-Society" (VOSTS). *Science Education*, *76*(5), 477-491.

Ainley, M., Hidi, S., & Berndorff, D. (2002). Interest, learning, and the psychological processes that mediate their relationship. *Journal of Educational Psychology, 94*, 545-561.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior.* Englewood-Cliffs, NJ: Prentice-Hall.

Ajzen, I., & Fishbein, M. (2005). The influence of attitudes on behavior. In D. Albarracín, B. T. Johnson, & M. P. Zanna (Eds.), *The handbook of attitudes* (pp. 173-221). Mahwah, NJ: Erlbaum.

American Association of University Women. (1991). *Shortchanging girls, shortchanging America.* Washington, DC: American Association of University Women.

Andre, T., Whigham, M., Chambers, S., & Hendrickson, A. (1999). Competence beliefs, positive affect, and gender stereotypes of elementary students and their parents about science versus other school subjects. *Journal of Research in Science Teaching, 36*, 719-747.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564-582.

Baars, B. J. (1986). *The cognitive revolution in psychology*. New York, NY: The Guilford Press.

Baker, D., & Leary, R. (1995). Letting girls speak out about science. *Journal of Research in Science Education*, *32*, 3-27.

Baker, D., Leary, R., & Trammell, R. (1992, March). *Where are the gender differences in science and what do they mean.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Boston, MA.

Beaton, A. E., Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., Smith, T. A., & Kelly, D. L. (1996). *Science achievement in the middle school years.* Boston College, MA: IEA.

Bem, B. (1970). *Beliefs, attitudes, and human affairs*. Belmont, CA: Coles Publishing Company.

Bentler, P. M. (1989). *EQS structural equation program manual*. Los Angeles, CA: BMDP Statistical Software.

Bevins, S., Brodie, E., & Brodie, M. (2005). *UK secondary school pupils' perceptions of science & engineering.* Unpublished report for the Engineering & Physical Sciences Research Council & the Particle Physics & Astronomy Research Council, Sheffield Hallam University.

Biles, R. (2005). *Illinois: A history of the land and its people*. DeKalb, IL: Northern Illinois University Press.

Black, L. (2011, November 7). Spending gap between state's rich, poor schools is vast. *Chicago Tribune*. Retrieved from http://articles.chicagotribune.com

Blalock. C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C., & Topperwein, M. (2008). In pursuit of validity: A comprehensive review of science attitude instruments. *International Journal of Science Education, 30*, 961-977.

Blank, R. K. (2013). Science instructional time is declining in elementary schools: What are the implications for student achievement and closing the gap? *Science Education, 97*(6), 830-847.

Bloom, B. S. (1976). *Human characteristics of school learning.* New York, NY: McGraw.

Blosser, P. E. (1984). *Attitude research in science education*. ERIC Clearinghouse of Science, Mathematics and Environmental Education Information Bulletin. Columbus, OH: Ohio State University.

Boylan, C. R., Hill, D. M., Wallace A. R., & Wheeler A. E. (1992). Beyond stereotypes, *Science Education*, *76*, 465-476.

Breakwell, G. M., & Beardsell, S. (1992). Gender, parental and peer influences upon science attitudes and activities. *Public Understanding of Science, 1*, 183–197.

Brickhouse, N. W., & Potter, J. T. (2001). Young women's scientific identity formation in an urban context. *Journal of research in science teaching*, *38*(8), 965-980.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching*, *45*, 955-970.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*, 485– 499.

Brown, S. (1976). *Attitude goals in secondary school science.* Stirling, UK: University of Stirling.

Brown, T. A. (2006). *Confirmatory factor analysis for applied research.* New York, NY: Guilford.

Bush, V. (1945). *Science–the endless frontier. A report to the President on a program for postwar scientific research*. Washington, DC: U.S. Government Printing Office.

Butler, M. B. (1999). Factors associated with students' intentions to engage in science learning activities. *Journal of Research in Science Teaching, 36*, 455-473.

Campbell, P. (1988). *Rethinking research: Challenges for new and not so new researchers.* Washington, DC: Department of Education, Women's Educational Equity Act.

Cannon, R. K., & Simpson, R. D. (1985). Relationships among attitude, motivation, and achievement of ability grouped, seventh-grade, life science students. *Science Education, 69*, 121-138.

Carey, N., & Shavelson, R. (1988). Outcomes, achievement, participation, and attitudes. In R. J. Shavelson, L. M. McDonnell, & J. Oakes (Eds.), *Indicators for monitoring mathematics and science education* (pp. 147-191). Santa Monica, CA: Rand Corporation.

Catsambis, S. (1995). Gender, race, ethnicity, and science education in the middle grades. *Journal of Research in Science Teaching, 32*, 243-257.

Chang, C. Y., & Cheng, W. Y. (2008). Science achievement and students' self-confidence and interest in science: A Taiwanese representative sample study. *International Journal of Science Education, 30*(9), 1183–1200.

Chang, C.-Y., & Mao, S.-L. (1998). The effects of an inquiry-based instructional method on earth science students' achievement. (ERIC document reproduction service no. ED 418 858)

Chouinard, R., Karsenti, T., & Roy, N. (2007). Relations among competence beliefs, utility value, achievement goals, and effort in mathematics. *British Journal of Educational Psychology*, *77*(3), 501-517.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159.

Coleman, J. S. (1987). Families and schools. *Educational researcher*, *16*(6), 32-38.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94*, S95-S120.

Coleman, J. S. (1991). *Parental involvement in education*. Washington, DC: U.S. Dept. of Education, Office of Educational Research and Improvement, Programs for the Improvement of Practice.

Coleman, J. S., & Hoffer, T. (1987). *Public and private high schools: The impact of communities*. New York, NY: Basic Books.

Common Core IL (2013). *Common core: Real learning for real life*. Retrieved from http://commoncoreil.org/

Convert, B. (2005). Europe and the crisis in scientific vocations. *European Journal of Education, 40,* 361-366.

Costa, V. B. (1995). When science is "another world": Relationships between worlds of family, friends, school, and science. *Science Education, 79*(3), 313-333.

Crawley, F. E., & Black, C. B. (1992). Causal modeling of secondary science students' intentions to enroll in physics. *Journal of Research in Science Teaching, 29,* 585-599.

Crawley, F. E., & Coe, A. E. (1990). Determinations of middle school students' intention to enroll in a high school science course: An application of the theory of reasoned action. *Journal of Research in Science Teaching, 27*, 461-476.

Crawley, F. E., & Koballa, Jr., T. R. (1992). Hispanic-American students' attitudes toward enrolling in high school chemistry: A study of planned behavior and belief-based change. *Hispanic Journal of Behavioral Sciences*, *14*, 469-486.

Crawley. F. E., & Koballa, T. R. (1994). Attitude research in science education: Contemporary models and methods. *Science Education, 78*, 35-56.

Cronbach, L. J., & Meehl, P.E. (1955). Construct validity for psychological tests. *Psychological Bulletin*, *52*, 281-302.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: Have they changed since 1980? *International Journal of Science Education*, *22*, 557-570.

DeBacker, T. K., & Nelson, R. M. (2000). Motivation to learn science: Differences related to gender, class type, and ability. *Journal of Educational Research*, *93*(4), 245-255.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice*. New York, NY: Teacher's College Press.

Deboer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37,* 582-601.

Deci, E. L. (1992). The relation of interest to the motivation of behavior: A self-determination theory perspective. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 43-70). Hillsdale, NJ: Erlbaum.

Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education.* New York, NY: Macmillan.

Dillon, W. R., & Goldstein, M. (1984). *Multivariate analysis: Methods and applications*.

Dimopoulos, K., & Smyrnaiou, Z., (2005). Factors related to students' interest in science learning. In D. Koliopoulos & A. Vavouraki (Eds.), *Science Education at Cross Roads: Meeting the Challenges of the 21st Century* (pp. 135-142). Athens, Greece: Association for Science Education.

Domestic Policy Council. (2006). *American competitiveness initiative.* Washington, DC: U.S. Government Office of Science and Technology Policy.

Ebenezer, J. V., & Zoller, U. (1993). Grade 10 students' perceptions of and attitudes toward science teaching. *Journal of Research in Science Teaching, 30,* 175-186.

Eccles, J., & Harold, R. (1993). Parent-school involvement during the early adolescent years. *The Teachers College Record*, *94*(3), 568-587.

Eccles, J., Wigfield, A., Harold, R. D., & Blumenfeld, P. (1993). Age and gender differences in children's self-and task perceptions during elementary school. *Child development*, *64*(3), 830-847.

Edwards, A. L. (1957). *Techniques of attitude scale construction*. New York, NY: Appleton Century Crofts.

Ertepinar, H., & Geban, O. (1996). Effect of instruction supplied with the investigative-oriented laboratory approach on achievement in a science course. *Educational Research, 38*, 333-344.

Farenga, S. J., & Joyce, B. A. (1998). Science-related attitudes and science course selection: A study of high-ability boys and girls. *Roeper Review*, *20*(4), 247–251.

Ferry, T. R., Fouad, N., & Smith, P. L. (2000). The role of family context in a social cognitive model for career-related choice behavior: A math and science perspective. *Journal of Vocational Behavior, 57,* 348-364.

Finson, K. D. (2002). Drawing a scientist: What we do and do not know after fifty years of drawings. *School Science and Mathematics, 102*, 335-345.

Fishbein, M. (1967). A consideration of beliefs, and their role in attitude measurement. In Martin Fishbein (Ed.), *Attitude theory and measurement* (pp. 257-266). New York, NY: Wiley.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research.* Reading, MA: Addison-Wesley.

Floyd, F. J., & Widaman, K. F. (1995). Factor analysis in the development and refinement of clinical assessment instruments. *Psychological assessment*, *7*(3), 286-299.

Fraser, B. J. (1980). Science teacher characteristics and student attitudinal outcomes. *School Science and Mathematics, 80*, 300-308.

Fraser, B. J. (1982). Development of short forms of several classroom environment scales. *Journal of Educational Measurement*, *19*(3), 221-227.

Fraser, B. J., & Kahle, J. B. (2007). Classroom, home and peer environment influences on student outcomes in science and mathematics: An analysis of systemic reform data. *International Journal of Science Education*, *29*(15), 1891-1909.

Fraser, B. L. (1978). Development of a test of science-related attitudes. *Science Education*, *62,* 509-515.

Freedman, M. P. (2002). The influence of laboratory instruction on science achievement and attitude toward science across gender differences. *Journal of Women and Minorities in Science and Engineering*, *8*, 191-200.

Fung, Y. Y. H. (2002). A comparative study of primary and secondary school students' images of scientists. *Research in Science and Technological Education*, *20*, 199-213.

Furman, M., & Barton, A. C. (2006). Capturing urban student voices in the creation of a science mini-documentary. *Journal of Research in Science Teaching*, *43*(7), 667-694.

Galbraith, S., Bowden, J., & Mander, A. (2014). Accelerated longitudinal designs: An overview of modelling, power, costs and handling missing data. *Statistical methods in medical research.* DOI: 0962280214547150

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research: An introduction.* White Plains, NY: Longman.

Gardner, P. L. (1975). Attitude to science: A review. *Studies in Science Education*, *2*(1), 1–41.

Gardner, P. L. (1985). Interests in science and technology education: an international overview. In M. Lehrke, L. Hoffmann, & P. L. Gardner (Eds.), *Interests in science and technology education: 12th IPN symposium (2-6 June 1984)*. Kiel, Germany: IPN, Institute of Science Education.

Gatignon, H. (2010). *Confirmatory Factor Analysis in Statistical analysis of management data*. DOI: 10.1007/978-1-4419-1270-1_4

Geban, O., Askar, P., & Ozkan, I. (1992). Effects of computer simulations and problems solving approaches on high school students. *Journal of Educational Research, 86*, 5-10.

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education and Technology, 9*, 213-225.

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education, 28*, 571-589.

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS: 88. *Science Education*, *82*, 93-109.

Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*, 689-703.

Gibson, H. L. (1998). Case studies of an inquiry-based science programs' impact on students' attitudes towards science and interest in science careers. (ERIC document reproduction service no. ED 417 980)

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education, 86*(5), 693–705.

Gilmartin, S. K., Li, E., & Aschbacher, P. (2006). The relationship between interest in physical science/engineering, science class experiences, and family contexts: Variations by gender and race/ethnicity among secondary students. *Journal of Women and Minorities in Science and Engineering, 12*, 179-207.

Greenfield, A. (1997). Gender- and grade-level differences in science interest and participation. *Science Education*, 81(3), 259-276.

Hadden, R. A., & Johnstone, A. H. (1983). Secondary school pupils' attitudes to science: The year of erosion. *European Journal of Science Education, 5*, 309-318.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of student, teacher, and learning environment variables to attitudes toward science. *Science Education*, *66*(5), 671-687.

Haladyna, T., & Shaughnessy, J. (1982). Attitudes toward science: A quantitative synthesis. *Science Education, 66,* 547-563.

Hale, J. L., Householder, B. J., & Greene, K. L. (2002). The theory of reasoned action. In J. P. Dillard & L. Shen (Eds.), *The persuasion handbook: Developments in theory and practice* (pp. 259-286). London, UK: Sage.

Hall, R. M., & Sandler, B. R. (1982). The classroom climate: A chilly one for women? (ERIC document reproduction service no. ED 215 628)

Halloun, I. (1997). Views about science and physics achievement: The VASS story. In E. F. Redish & J. S. Rigden (Eds.), *The changing role of physics departments in modern universities. American Institute of Physics Proceedings* (pp. 605-613). College Park, MD: American Institute of Physics Press.

Halloun, I. (2001). Student views about science: A comparative survey. Beirut, Lebanon: Educational Research Center, Lebanese University.

Hamerick, L., & Harty, H. (1987). Influence of resequencing general science content on the science achievement, attitudes toward science, and interest in science of sixth grade students. *Journal of Research in Science Teaching, 24*(1), 15–25.

Harpole, S. H. (1987). *The relationship of gender and learning styles to achievement and laboratory skills in secondary school chemistry students*. Paper presented at the Annual Meeting of the Mid-South Educational Research Association. (ERIC Document Reproduction No. ED 288 728)

Harty, H., & Beall, D. (1984). Toward the development of a children's science curiosity measure. *Journal of Research in Science Teaching, 21*(4), 425-436.

Hasan, O. E. (1985). An investigation into factors affecting attitudes toward science of secondary school students in Jordan. *Science Education, 69*(1), 1–18.

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching, 39*, 870-888.

Head, J. O. (1985). *The personal response to science.* Cambridge, UK: Cambridge University Press.

Heberlein, T. A., & Baumgartner, R. (1978). Factors affecting response rates to mailed questionnaires: A quantitative analysis of the published literature. *American Sociological Review, 43*, 447-462.

Heikkinen, H. W. (1973). *A study of factors influencing student attitudes toward the study of high school chemistry* (Doctoral dissertation). University of Maryland, College Park, MD.

Henderson, A. T., & Berla, N. (1994). *A new generation of evidence: The family is critical to student achievement*. Columbia, MD: National Committee for Citizens in Education. (ERIC Document No. ED375968)

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*(4), 549–571.

Hill, G. D., Atwater, M. M., & Wiggins, J. (1995). Attitudes toward science of urban 7th grade life-science students over time, and the relationship to future plans, family, teacher, curriculum and school. *Urban Education, 30,* 71-92.

Hoover-Dempsey, K. V., Bassler, O. C., & Burow, R. (1995). Parents' reported involvement in students' homework: Strategies and practices. *The Elementary School Journal, 95*, 435-450.

Hovland, C. I., Janis, I. L., & Kelley, H. H. (1953). *Communication and persuasion*. New Haven, CT: Yale University Press.

Hough, L. W., & Piper, M. K. (1982). The relationship between attitudes toward science and science achievement. *Journal of Research in Science Teaching, 19,* 33-38.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1-55.

Huang, G., Taddese, N., & Walter, E. (2000). *Entry and persistence of women and minorities in college science and engineering education*. Research and development report for National Center for Education Statistics. Jessup, MD: Ed Pubs.

Illinois Lead State Summary. (2011). *Next generation science standards.* Retrieved from http://www.nextgenscience.org/Illinois

Illinois State Board of Education. (2012). *A profile of Illinois public schools: Selections from the school report card files.* Retrieved from http://www.isbe.net/assessment/pdfs/report_card/2012/pub-school-profile12.pdf

Illinois State Board of Education. (2015). *Illinois Report Card 2013-2014*. Retrieved from http://illinoisreportcard.com/default.aspx?tsource=home/

Institute for Work & Health, Toronto. (2009, winter). What researchers mean by cross-sectional vs. longitudinal studies. *At Work*, Issue 55. Retrieved from https://www.iwh.on.ca/wrmb/cross-sectional-vs-longitudinal-studies

Jaus, H. H. (1977). Activity-oriented science: Is it really that good? *Science and Children, 14*, 26–27.

Jayaratne, T. E., Thomas, N. G., & Trautmann, M. (2003). Intervention program to keep girls in the science pipeline: Outcome differences by ethnic status. *Journal of Research in Science Teaching*, *40*, 393-414.

Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science & Technological Education, 23,* 41–57.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education*, *84*(2), 180-192.

Jöreskog, K. G. (1971). Statistical analysis of sets of congeneric tests. *Psychometrika*, *36*(2), 109-133.

Jöreskog, K. G., & Sorbom, D. (1989). *LISREL 7: User's reference guide*. Mooresville, IN: Scientific Software.

Jung, C. G. (1971/1921). *Psychological types*. Princeton, NJ: Princeton University Press.

Kahle, J. B. (1984). Girls in school/Women in science. *Paper presented at the Annual Women's Studies Conference.* (ERIC Document Reproduction Service No. ED 243 785)

Kahle, J., & Lakes, M. (1983). The myth of equality in the science classrooms. *Journal of Research in Science Teaching, 20*, 131-140.

Keeves, J. P. (1975). The home, the school, and achievement in mathematics and science. *Science Education*, *59*, 439-460.

Keeves, J., & Kotte, D. (1996). Patterns of science achievement: International comparisons. In J. Parker, L. Rennie, & B. Fraser (Eds.), *Gender science and mathematics: Shortening the shadow* (pp. 77-94). Dordrecht, Netherlands: Kluwer Academic Publishers.

Kelly, A. (1986). The development of girls' and boys' attitudes to science: A longitudinal study. *European Journal of Science Education*, *8*, 399-412.

Keys, W. (1987). *International studies in pupil performance: Aspects of science education in English schools.* Windsor, UK: NFER-Nelson.

Klopfer, L. E. (1971). Evaluation of learning science. In B. S. Bloom, T. Y. Hastings & G. F. Madaus (Eds.), *Handbook of formative and summative evaluation of student learning*, (pp. 559-642). New York, NY: McGraw-Hill.

Koballa Jr., T. R. (1988a). Attitude and related concepts in science education. *Science Education, 72*(2), 115-126.

Koballa Jr., T. R. (1988b). The determinants of female junior high school students' intentions to enroll in elective physical science courses in high school: Testing the applicability of the theory of reasoned action. *Journal of Research in Science Teaching, 25*, 479-492.

Koballa Jr., T. R. (1995). Children's attitudes toward learning science. In S. Glynn & R. Duit (Eds.), *Learning science in the schools* (pp. 59-84). Mawhah, NJ: Lawrence Erlbaum.

Koballa Jr., T. R., & Crawley, F. E. (1985). The influence of attitude on science teaching and learning. *School Science and Mathematics, 85*, 222–232.

Koballa Jr., T. R., & Glynn, S. M. (2007). Attitudinal and motivational constructs in science learning. *Handbook of research on science education* (pp. 75-102). Mahwah, NJ: Lawrence Erlbaum.

Kotte, D. (1992). *Gender differences in science achievement in 10 countries.* Frankfurt, Germany: Peter Lang.

Krapp, A. (2000). Interest and human development during adolescence: An educational-psychological approach. In J. Heckhausen (Ed.), *Motivational psychology of human development* (pp. 109–128). London, UK: Elsevier.

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives: The classification of educational goals. Handbook II: The affective domain*. New York, NY: David McKay.

Kremer, B. K., & Walberg, H. J. (1981). A synthesis of social and psychological influences on science learning. *Science Education, 65*, 11-23.

Krynowsky, R. A. (1988). Problems in assessing student attitude in science education: A partial solution. *Science Education, 72*(5), 575–584.

Laukenmann, M., Bleicher, M., Fu, S., Gläser-Zikuda, M., Mayring, P., & von Rhöneck, C. (2003). An investigation of the influence of emotional factors on learning in physics instruction. *International Journal of Science Education, 25*(4), 489–507.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York, NY: Cambridge University Press.

Lester, F., Garofalo, J., & Kroll, D. (1989). Self-confidence, interest, beliefs and metacognition: Key influences on problem solving behavior. In D. McLeod & V. Adams (Eds.), *Affect and mathematical problem solving.* New York, NY: Springer-Verlag.

Lewis, J. E., & Potter, I. C. (1961). *The teaching of science in the elementary school*. Englewood Cliffs, NJ: Prentice-Hall.

Liaghatdar, M. J., Soltani, A., & Abedi, A. (2011). A validity study of attitudes toward science scale among Iranian secondary school students. *International Education Studies, 4*(4), 36-46.

Lindahl, B. (2007, March). *A longitudinal study of students' attitudes towards science and choice of career*. Paper presented at the 80th NARST International Conference, New Orleans, LA.

Liska, A. E. (1984). A critical examination of the causal structure of the Fishbein/Ajzen attitude–behavior model. *Social Psychology Quarterly, 47*, 61–74.

Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. *International Journal of Science Education, 28*(6), 591-613.

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, *32*(5), 669-685.

Marsh, H. W. (1992). Content specificity of relations between academic achievement and academic self-concept. *Journal of Educational Psychology, 84*, 35-42.

Martin, M. O. (1996). Third international mathematics and science study: An overview. In M. O. Martin, & D. L. Kelly, *Third international mathematics and science study: Technical report, Vol. 1* (pp. 1-1–1-19). Boston College, MA: lEA.

Mattheis, F. E., & Nakayama, G. (1988). Effects of a laboratory-centered inquiry program on laboratory skills, science process skills, and understanding of science knowledge in middle grades students. (ERIC document reproduction service no. ED 307 148)

Mayberry, M. (1998). Reproductive and resistant pedagogies: The comparative roles of collaborative learning and feminist pedagogy in science education. *Journal of Research in Science Teaching*, *35*, 443-459.

McNeill, C. T., & Butts, D. P. (1981). *Scientific literacy in Georgia*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. (ERIC Document Reproduction Service No. ED 202 680)

Messick, S. (1989). Meaning and values in test validation: The science and ethics of assessment. *Educational Researcher, 18*(2), 5-11.

Messick, S. (1998). Test validity: A matter of consequence. *Social Indicators Research*, *45*, 1-3.

Millar, R. (1991). Why is science hard to learn? *Journal of Computer Assisted Learning*, *7*(2), 66-74.

Millar, R., & Osborne, J. (Eds.). (1998). *Beyond 2000: Science education for the future.* London, UK: King's College.

Misiti, F. L., Shrigley, R. L., & Hanson, L. (1991). Science attitude scale for middle school students. *Science education, 75*(5), 525-540.

Moffat, N. (1992). *Girls and science careers: Positive attitudes are not enough.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. (ERIC Document Reproduction No. ED 362 400)

Moore, R. W., & Hill Foy, R. L. (1997). The scientific attitude inventory: A revision (SAI II). *Journal of Research in Science Teaching, 34*, 327-336.

Moore, R. W., & Sutman, F. X. (1970). The development, field test and validation of an inventory of scientific attitudes. *Journal of Research in Science Teaching, 7*, 85-94.

Morrell, P. D., & Lederman, N. G. (1998). Student's attitudes toward school and classroom science: Are they independent phenomena? *School Science and Mathematics*, *98*, 76-83.

Munby, H. (1979). *An investigation into the measurement of attitudes in science education.* Kingston, ON: Faculty of Education, Queen's University.

Munby, H. (1982). The impropriety of "panel of judges" validation in science attitude scales: A research comment. *Journal of Research in Science Teaching, 19*(7), 617–619.

Munby, H. (1983). Thirty studies involving the "scientific attitude inventory": What confidence can we have in this instrument? *Journal of Research in Science Teaching, 20*(2), 141-162.

Murphy, C., & Beggs, J. (2003). Children's attitudes towards school science. *School Science Review, 84*(308), 109-116.

Nagy, P. (1978). Subtest formation by cluster analysis of the Scientific Attitude Inventory. *Journal of Research in Science Teaching, 15,* 355-360.

National Academy of Science, National Academy of Engineering, & Institute of Medicine. (2006). *Beyond bias and barriers: Fulfilling the potential of women in academic science and engineering*. Washington, DC: National Academies Press.

National Association of Educational Progress. (2011). *Science Teacher Questionnaire*. Retrieved from https://nces.ed.gov/nationsreportcard/bgquest.aspx

National Center for Educational Statistics. (2006). *Common core of data: Identification of rural locales.* Retrieved from https://nces.ed.gov/ccd/rural_locales.asp

National Center for Educational Statistics. (2015). *Search for Schools and Colleges.* Retrieved from http://nces.ed.gov/globallocator/

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: U.S. Department of Education.

National Research Council. (1996). *From analysis to action: Undergraduate education in science, mathematics, engineering, and technology*. Washington, DC: Author.

National Research Council. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: The National Academies Press.

National Science Board. (2001). *Toward a more effective role for the U.S. government in international science and engineering*. Arlington, VA: National Science Foundation.

National Science Board. (2010). *Preparing the next generation of STEM innovators: Identifying and developing our nation's human capitol.* Arlington, VA: National Science Foundation.

Nieswandt, M. (2005). Attitudes toward science: A review of the field. In S. Alsop (Ed.), *Beyond Cartesian Dualism* (pp. 41-52). Dordrecht, Netherlands: Springer.

Noll, V. H. (1935). Measuring the scientific attitude. *The Journal of Abnormal and Social Psychology*, *30*(2), 145.

Norwich, B., & Duncan, J. (1990). Attitudes, subjective norm, perceived preventive factors, intentions and learning science: Testing a modified theory of reasoned action. *British Journal of Educational Psychology, 60,* 312-321.

Oates, C., Gunstone, D., Northfield, J., & Fensham, P. (1980). *Science education—Australian practices and perspectives, culture and curriculum series*. Canberra, Australia: The Curriculum Development Centre.

Office of Accountability. (2014). *Stats and facts*. Retrieved from http://www.cps.edu.

Oliver, J. S., & Simpson, R. D. (1988). Influences of attitude toward science, achievement motivation, and science self concept on achievement in science: a longitudinal study. *Science Education*, *72*, 143–155.

Oppenheim, A. N. (1992). *Questionnaire design, interviewing and attitude measurement.* London, UK: Pinter.

Ormerod, M. B., & Duckworth, D. (1975). *Pupils' attitudes to science: A review of research.* Atlantic Highlands, NJ: Humanities Press.

Osborne, J., & Collins, S. (2000). *Pupils'& parents' views of the school science curriculum*. London, UK: King's College.

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: A focus-group study. *International Journal of Science Education*, *23,* 441–467.

Osborne, J., Driver, R., & Simon, S. (1998). Attitudes to science: Issues and concerns. *School Science Review, 79*(288), 27-33.

Osborne, J., Simon, S., & Collins, S. (2003). Attitude towards science: A review of the literature and its implications. *International Journal of Science Education, 25,* 1049-1079.

Osborne, J., Simon, S., & Tytler, R. (2009, April). *Attitudes towards science: An update.* Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). *The measurement of meaning* (Vol. 47). Urbana, IL: University of Illinois Press.

Owen, S. V., Toepperwein, M. A., Marshall, C. E., Lichtenstein, M. J., Blalock, C. L., Liu, Y., Pruski, L. A., & Grimes, K. (2007). Finding pearls: Psychometric reevaluation of the Simpson-Troost attitude questionnaire (STAQ). *Science Education, 92,* 1076-1095.

Padilla, M. J., Okey, J. R., & Garrand, K. (1984). The effects of instruction on integrated science process skill achievement. *Journal of Research in Science Teaching, 21*, 277-287.

Papanastasiou, C. (2002). School, teaching and family influence on student attitudes toward science: Based on TIMSS data for Cyprus. *Studies in Educational Evaluation, 28,* 71-86.

Patrick, H., & Yoon, C. (2004). Early adolescents' motivation during science investigation. *Journal of Educational Research, 97*, 319-28.

Pearl, R. E. (1974). The present status of science attitude measurement: History, theory, and availability of measurement instruments. *School Science and Mathematics, 73,* 375–381.

Pell, T., & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal in Science Education, 23,* 847-862.

Peterson, R. W., & Carlson, G. R. (1979). A summary of research in science education–1977. *Science Education, 63*(4), 497–500.

Petty, R. E., & Cacioppo, J. T. (1986). *Communication and persuasion: Central and peripheral routes to attitude change*. New York, NY: Springer-Verlag.

Piburn, M. D., & Baker, D. R. (1993). If I were the teacher…qualitative study of attitude toward science. *Science Education*, *77*(4), 393-406.

Public Schools K12. (2011). *School statistics and demographics* (Effingham Public Schools). Retrieved from http://publicschoolsk12.com

Purkey, S. C., & Smith M. S., (1983). Effective schools: A review. *The Elementary School Journal, 83,* 427-452.

Purser, R. K., & Renner, J. W. (1983). Results of two tenth grade biology teaching procedures. *Science Education, 67*, 85-98.

Ramsden, J. M. (1998). Mission impossible?: Can anything be done about attitudes to science? *International Journal of Science Education, 20*, 125-137.

Raudenbush, S. W., & Bryk. A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (Vol. 1). Thousand Oaks, CA: Sage.

Raykov, T. (2001). Bias of coefficient alpha for fixed congeneric measures with correlated errors. *Applied Psychological Measurement*, *25*(1), 69-76.

Rennie, L. J., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools: Results of a national study. *Research in Science Education*, *31*(4), 455-498.

Rennie, L. J., & Punch, K. F. (1991). The relationship between affect and achievement in science. *Journal of Research in Science Teaching, 28,* 193-209.

Renninger, K. A., Hidi, S., & Krapp, A. (Eds.). (1992). *The role of interest in learning and development*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102–119). New York, NY: MacMillan.

Robertson, I. J. (2000). Influences on choice of course made by university Year 1 bioscience students—A case study. *International Journal of Science Education*, *22*, 1201-1218.

Rokeach, M. (1973). *The nature of human values.* New York, NY: The Free Press.

Rosseel, Y. (2010). *Mplus estimators: MLM and MLR* [PowerPoint slides]. Retrieved from http://users.ugent.be/~yrosseel/lavaan/utrecht2010.pdf

Saunders, W. L., & Shepardson, D. (1987). A comparison of concrete and formal science instruction upon science achievement and reasoning ability of sixth grade students. *Journal of Research in Science Teaching, 24*, 39-51.

Schibeci, R. A. (1984). Attitudes to science: An update. *Studies in Science Education, 11*, 26–59.

Schibeci, R. A. (1989). Home, school, and peer group influences on student attitudes and achievement in science. *Science Education*, *73*(1), 13-24.

Schibeci, R., & Lee, L. (2003). Portrayals of science and scientists, and "science for citizenship." *Research in Science and Technological Education*, *21*, 177-192.

Schibeci, R. A., & Riley, J. P. (1983). *Influence of student background on science attitudes and achievement.* Paper presented at the annual meeting of the American Educational Research Association, Montreal, P.Q., Canada.

Schneider, L. S., & Renner, J. W. (1980). Concrete and formal teaching. *Journal of Research in Science Teaching, 17*, 503-517.

Schreiner, C., & Sjøberg, S. (2004). *Sowing the seeds of ROSE: Background, rationale, questionnaire development and data collection for ROSE (the Relevance of Science Education)—A comparative study of students' views of science and science education.* Oslo, Norway: University of Oslo, Department of Teacher Education and School Development.

Schweingruber, H., Keller, T., & Quinn, H. (Eds.). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C.: National Academies Press.

Shaw, M. E., & Wright, J. M. (1968). *Scales for the measurement of attitude*. New York, NY: McGraw Hill.

Shaughnessy, J., Shaughnessy, J. M., & Haladyna, T. M. (1983). Relations of student, teacher, and learning environment variables to attitude toward mathematics. *School Science and Mathematics, 83*(1), 21-38.

Sheridan, D. J. (2006). Reversing the decline of academic medicine in Europe. *Lancet, 367,* 1698-1701.

Shrigley, R. L. (1976). Credibility of the elementary science methods instructor as perceived by students: A model of attitude modification. *Journal of Research in Science Teaching, 13,* 449-453.

Shrigley, R. L. (1978). The persuasive communication model: A theoretical approach for attitude change in science education. *Journal of Research in Science Teaching, 15,* 335-341.

Shrigley, R. L. (1983). The attitude concept and science teaching. *Science Education*, *67*(4), 425-442.

Shrigley, R. L. (1990). Attitude and behavior correlates. *Journal of Research in Science Teaching, 27,* 97-113.

Shrigley, R. L., & Koballa, Jr., T. R. (1992). A decade of attitude research based on Hovland's Learning Theory Model. *Science Education, 76,* 17-42.

Shrigley, R. L., Koballa, T. R., & Simpson, R. D. (1988). Defining attitude for science educators. *Journal of Research in Science Teaching, 25,* 659-678.

Siegel, M. A., & Ranney, M. A. (2003). Developing the Changes in Attitude about the Relevance of Science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching, 40,* 757-775.

Simpson, R. D., & Oliver, J. S. (1985). Attitude toward science and achievement motivation profiles of male and female science students in grades six through ten. *Science Education*, *69*(4), 511–525.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, *74*, 1-18.

Simpson, R. D., & Troost, K. M. (1982). Influences on commitment to learning of science among adolescent students. *Science Education*, *66*, 763-781.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*(6), 323-332.

Sjøberg, S., & Schreiner, C. (2005). How do learners in different cultures relate to science and technology? *Asia-Pacific Forum on Science Learning and Teaching*, *6*(2).

Skinner, R., & Barcikowski, R. S. (1973). Measuring specific interests in biological, physical and earth sciences in intermediate grade levels. *Journal of Research in Science Teaching, 10*(2), 153-158.

Song, J., & Kim, K. S. (1999). How Korean students see scientists: The images of the scientist. *International Journal of Science Education*, *21*(9), 957-977.

Speering, W., & Rennie, L. J. (1996). Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Education, 26*, 283-298.

Stake, J. E., & Mares, K. R. (2001). Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation. *Journal of Research in Science Teaching*, *38*(10), 1065-1088.

Stake, J. E., & Nickens, S. D. (2005). Adolescent girls' and boys' science peer relationships and perceptions of the possible self as scientist. *Sex Roles*, *52*(1-2), 1-11.

Stevenson, D. L., & Baker, D. P. (1987). The family-school relation and the child's school performance. *Child Development, 58*(5), 1348-1357.

Sudas, L. G., & Iurasova, M. V. (2006). College students' attitudes toward science and scientific work. *Russian Education and Society, 48,* 25-41.

Sullivan, R. J. (1979). Students' interests in specific science topics. *Science Education*, *63*(5), 591-598.

Summers, R. (2012). *Development and validation of an instrument to assess precollege Arabic speaking students' attitudes toward science* (Unpublished Master's Thesis). University of Illinois at Urbana-Champaign, Urbana, Illinois.

Sutcliffe, J. (1998, May 22). Age weakens thirst for knowledge. *Times Educational Supplement*.

Talton, E. L., & Simpson, R. D. (1985). Relationships between peer and individual attitudes toward science among adolescent students. *Science Education, 69,* 19–24.

Talton, E. L., & Simpson, R. D. (1986). Relationship of attitudes toward self, family, and school with attitude toward science among adolescents. *Science Education, 70,* 365–374.

Talton, E. L., & Simpson, R. D. (1987). Relationships of attitude toward classroom environment with attitude toward and achievement in science among tenth grade biology students. *Journal of Research in Science Teaching, 24,* 507–525.

Templin, J. (2014). *Applied multilevel models for cross-sectional data* [PowerPoint slides]. Retrieved from http://jonathantemplin.com/

Thompson, J., & Soyibo, K. (2002). Effects of lecture, teacher demonstrations, discussion and practical work on 10th graders' attitudes to chemistry and understanding of electrolysis. *Research in Science & Technological Education*, *20*(1), 25-37.

Thorkildsen, R., & Stein, M. R. S. (1998). Is parent involvement related to student achievement? Exploring the evidence. *Research Bulletin*, *22*, 17-20.

Thurstone, L. L. (1928). Attitudes can be measured. *The American Journal of Sociology, 33,* 529–554.

Tippins, D. J. (1991). *The relationship of science self-efficacy and gender to ninth grade students' intentions to enroll in elective science courses*. Paper presented at the Annual Meeting of the American Educational Research Association. (ERIC Document Reproduction Service No. ED 350 144)

Tobias, S. (1994). Interest, prior knowledge and learning. *Review of Educational Research, 64,* 37-54.

Tuan, H.-L., Chin, C.-C., & Shieh, S.-H. (2005). The development of a questionnaire to measure students’ motivation towards science learning. *International Journal of Science Education, 27*(6), 639–654.

Tytler, R., & Osborne, J. (2012). Student attitudes and aspirations towards science. In B. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 597-625). Dordrecht, Netherlands: Springer.

Tytler, R., Osborne, J. F., Williams, G., Tytler, K., Clark, J. C., Tomei, A., et al. (2008). *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition. A review of the literature concerning supports and barriers to Science, Technology, Engineering and Mathematics engagement at Primary-Secondary transition.* Commissioned by the Australian Department of Education, Employment and Workplace Relations. Melbourne, Australia: Deakin University.

United States Department of Labor. (2007). *The STEM workforce challenge*. Washington, DC: Author.

Wareing, C. (1982). Developing the WASP: Wareing attitude toward science protocol. *Journal of Research in Science Teaching, 19*(8), 639–645.

Wareing, C. (1990). A survey of antecedents of attitudes toward science. *Journal of Research in Science Teaching, 27*(4), 371–386.

Washton, N. S. (1971). Improving elementary teacher education in science. In D. L. Williams, & W. L. Herman, Jr. (Eds.), *Current research in elementary school science*. New York, NY: Macmillan.

Weinburgh, M. H., & Steele, D. (2000). The modified attitudes toward science inventory: Developing an instrument to be used with fifth grade urban students. *Journal of Women and Minorities in Science and Engineering*, *6*(1), 87-94.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, *9*(5), 2-3.

Willson, V. L. (1983). A meta-analysis of the relationship between science achievement and science attitude: Kindergarten through college. *Journal of Research in Science Teaching, 20*, 839-850.

Wollman, W. T., & Lawson, A. E. (1978). The influence of instruction on proportional reasoning in seventh graders. *Journal of Research in Science Teaching, 15*, 227-232.

Woolnough, B. E., Guo, Y., Leite, M. S., Almeida, M. J. D., Ryu, T., Wang, Z., & Young, D. (1997). Factors affecting student choice of career in science and engineering: Parallel studies in Australia, Canada, China, England, Japan and Portugal. *Research in Science & Technological Education*, *15*, 105-121.

Wright, J. D., & Hounshell, P. B. (1981). A survey of interest in science for participants in a junior science and humanities symposium. *School Science and Mathematics, 81*, 378-382.

Wyer, M. (2003). Intending to stay: Images of scientists, attitudes toward women and gender as influences on persistence among science and engineering majors. *Journal of Women and Minorities in Science and Engineering, 9*, 1-16.

Wynn, D. C., & Bledsoe, J. C. (1967). Factors related to gain and loss of scientific interest during high school. *Science Education, 51*, 67-74.

van Aalst, H. F. (1985) A model of interest, motivation and learning. In M. Lehrke, L. Hoffman & P. L. Gardner (Eds.), *Interests in science and technology education: Conference proceedings* (pp. 49-57). Kiel, Germany: IPN.

Vogt, W. P., & Johnson, R. B. (2011). *Dictionary of statistics and methodology: A non-technical guide for the social sciences* (4th ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Appendix A

US-ASSASS Student Survey

مؤسسة قطر
Qatar Foundation

THE ASSASS SURVEY OF ATTITUDES TOWARD SCIENCE

For Precollege Students in Grades 5 - 12

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

DEVELOPED AS PART OF THE QIAS PROJECT WITH GENEROUS CONTRIBUTIONS FROM THE QATAR FOUNDATION

COLLEGE OF THE NORTH ATLANTIC QATAR

Instructions

There are no "right" or "wrong" answers to the following questions. We are simply interested in your feelings about a number of issues related to science and science learning.

- Indicate the extent to which you agree or disagree with each the following statements.
- Place a check mark (✓) or an (✗) on the response that best represents your answer.
- Check **only one answer** for each question.

– If you "Strongly disagree" with a statement, then you should check:

Strongly disagree	Disagree	Not sure	Agree	Strongly agree
✓	○	○	○	○

– If you "Disagree" with a statement, then you should check:

Strongly disagree	Disagree	Not sure	Agree	Strongly agree
○	✓	○	○	○

– If you are "Not sure" whether you agree or disagree with a statement, then you should check:

Strongly disagree	Disagree	Not sure	Agree	Strongly agree
○	○	✓	○	○

– If you "Agree" with a statement, then you should check:

Strongly disagree	Disagree	Not sure	Agree	Strongly agree
○	○	○	✓	○

– If you "Strongly agree" with a statement, then you check:

Strongly disagree	Disagree	Not sure	Agree	Strongly agree
○	○	○	○	✓

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
1. I enjoy science	○	○	○	○	○
2. Learning science is not important for my future success	○	○	○	○	○
3. Scientists are highly respected	○	○	○	○	○
4. We do a lot of interesting activities in science class	○	○	○	○	○
5. Most people should understand science because it affects their lives	○	○	○	○	○
6. I consider my family's advice about my future career	○	○	○	○	○
7. I will study science if I get into college	○	○	○	○	○
8. I am sure I can do well on science tests	○	○	○	○	○
9. Scientific discoveries do more harm than good	○	○	○	○	○
10. I usually give up when I do not understand a science concept	○	○	○	○	○
11. Science is one of the most interesting school subjects	○	○	○	○	○
12. Teachers encourage me to understand concepts in science classes	○	○	○	○	○
13. Members of my family work in scientific careers	○	○	○	○	○
14. Science classes will help prepare me for college	○	○	○	○	○
15. Science is easy for me	○	○	○	○	○
16. My science teachers are very good	○	○	○	○	○
17. I will not pursue a science-related career in the future	○	○	○	○	○
18. I like to watch TV programs about science	○	○	○	○	○
19. I cannot understand science even if I try hard	○	○	○	○	○
20. Science is useful in solving everyday life problems	○	○	○	○	○
21. I will become a scientist in the future	○	○	○	○	○
22. My interest in science depends on my teacher	○	○	○	○	○
23. Much of what I learn in science classes is useful in my life outside of school	○	○	○	○	○
24. I look forward to science activities in class	○	○	○	○	○
25. I can understand difficult science concepts	○	○	○	○	○
26. A job as a scientist would be boring	○	○	○	○	○
27. I like to learn more about science	○	○	○	○	○
28. I really enjoy science lessons	○	○	○	○	○
29. I will continue studying science after I leave school	○	○	○	○	○
30. My family encourages my interest in science	○	○	○	○	○

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
31. I am confident that I can understand science	○	○	○	○	○
32. We live in a better world because of science	○	○	○	○	○
33. I would enjoy working in a science-related career	○	○	○	○	○
34. My parents influence my thinking about my education	○	○	○	○	○
35. I will miss studying science when I leave school	○	○	○	○	○
36. My friends like science	○	○	○	○	○
37. Knowing science can help me make better choices about my health	○	○	○	○	○
38. My family encourages me to have a science-related career	○	○	○	○	○
39. I would like to do science experiments at home	○	○	○	○	○
40. I really like science	○	○	○	○	○
41. I try to learn science even if it is difficult	○	○	○	○	○
42. If I could choose, I would not take any more science in school	○	○	○	○	○
43. Scientists usually like to go to work even when they have a day off	○	○	○	○	○
44. Knowledge of science helps me protect the environment	○	○	○	○	○
45. Scientific work is only useful to scientists	○	○	○	○	○
46. Science will help me understand the world around me	○	○	○	○	○
47. My friends do well in science	○	○	○	○	○
48. If I work hard enough, I can learn difficult science concepts	○	○	○	○	○
49. There is a lot of memorization in science classes	○	○	○	○	○
50. I will take additional science courses in the future	○	○	○	○	○
51. It is important to know science in order to get a good job	○	○	○	○	○
52. Science lessons are a waste of time	○	○	○	○	○
53. I enjoy science lessons when I like the specific subject I am learning	○	○	○	○	○
54. Scientists do not have enough time for fun	○	○	○	○	○
55. I have a good feeling toward science	○	○	○	○	○
56. I care about what my friends think when I consider future careers	○	○	○	○	○
57. People with science-related careers have a normal family life	○	○	○	○	○
58. I do not like science	○	○	○	○	○
59. My science teachers motivate me to learn science	○	○	○	○	○

1. Date		2. School name								
3. Grade level	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8	☐ 9	4. Section (if any):		
5. Age		6. Gender	☐ Male	☐ Female						

7. Which of the following best describes you? Fill in one or more ovals.	8. How often do people in your home talk to each other in a language **other** than English (e.g., Spanish or Chinese)?
☐ White	
☐ Black or African American	☐ Never
☐ Asian	☐ Once in a while
☐ Hispanic or Latino	☐ About half of the time
☐ American Indian or Alaska Native	☐ Most of the time
☐ Native Hawaiian or other Pacific Islander	☐ All the time
☐ I don't know or I prefer not to respond	

9. How far in school did your father go?	10. How far in school did your mother go?
☐ He did not finish high school	☐ She did not finish high school
☐ He finished high school	☐ She finished high school
☐ He got a vocational diploma	☐ She got a vocational diploma
☐ He graduated from a community college	☐ She graduated from a community college
☐ He graduated from a university	☐ She graduated from a university
☐ I do not know	☐ I do not know

11. How often do you talk about things you learn at school with someone in your family?				
☐ Never	☐ Once every few weeks	☐ Once a week	☐ Two or three times a week	☐ Every day

12. Is there a computer at home that you can use?	☐ Yes	☐ No		13. Can you access the internet at home?	☐ Yes	☐ No

14. In my opinion, my science grades are:	☐ Not so good	☐ Average	☐ Good	☐ Very good	☐ Excellent

THANK YOU FOR COMPLETING THIS SURVEY

Appendix B

Science Teacher Survey

ILLINOIS

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Science Teacher Survey

Spring 2014

NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS

A Teacher Compliment to the ASSASS Survey of Attitudes toward Science developed with permission from NAEP and endorsed by the ISTA

ILLINOIS SCIENCE TEACHERS ASSOCIATION
www.ista-il.org

Instructions

Please know that there are not any right or wrong answers to the following questions. These questions will ask about your background, training, teaching practices, and attitudes toward science. The information you provide is intended to compliment the information collected from your students.

Note that there are a few questions which ask for details about the class section completing the student survey. If you have multiple teaching assignments or teach multiple sections, please respond with the participating student section in mind.

SECTION 1: BACKGROUND AND TRAINING

_____Years	Counting this year, how many years have you worked as an elementary or secondary teacher? If less than 6 months total experience, enter "0."

_____Years	Counting this year, how many years have you taught science in grades 5 through 12? If less than 6 months total experience, enter "0."

_____Years	Counting this year, how many years have you taught science at your currently assigned grade? If less than 6 months science teaching experience at your currently assigned grade, enter "0."

What is the highest academic degree you hold?

☐ High school diploma
☐ Associate's degree/vocational certification
☐ Bachelor's degree
☐ Master's degree
☐ Education specialist's or professional diploma (based on at least one year's work past master's degree)
☐Doctorate
☐Professional degree (e.g., M.D., LL.B., J.D., D.D.S.)

Did you have a major, minor, or special emphasis in any of the following subjects as part of your **undergraduate** coursework? Mark **one of** the following choices for each line.

a. Biology or other life science	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
b. Physics, chemistry, or other physical science	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No

c. Earth or space science	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
d. Mathematics or mathematics education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
e. Science education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
f. Engineering or engineering education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
g. Elementary or secondary education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
h. Special education (including students with disabilities)	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
i. English language learning	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No

Did you have the following subjects as part of your **graduate** coursework? Mark **one of** the following choices for each line.			
a. Biology or other life science	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
b. Physics, chemistry, or other physical science	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
c. Earth or space science	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
d. Mathematics or mathematics education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
e. Science education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
f. Engineering or engineering education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
g. Elementary or secondary education	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No
h. Special education (including students with disabilities)	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No

i. English language learning	☐ Yes, a major	☐ Yes, a minor or special emphasis	☐No

As part of either your undergraduate or graduate coursework, how many **advanced science** courses (such as physiology, molecular biology, or biochemistry) did you take?			
☐ None	☐ 1 or 2 courses	☐ 3 or 4 courses	☐ 5 or more courses

As part of either your undergraduate or graduate coursework, how many **science education** courses did you take?			
☐ None	☐ 1 or 2 courses	☐ 3 or 4 courses	☐ 5 or more courses

During the last **two years**, did you participate in or lead any of the following professional development activities **related to the teaching of science**? Mark **one of** the following choices for each line.			
a. College course taken after your first certification	☐Yes, I have participated	☐Yes, I have led	☐No
b. Workshop or training session	☐Yes, I have participated	☐Yes, I have led	☐No
c. Conference or professional association meeting	☐Yes, I have participated	☐Yes, I have led	☐No
d. Observational visit to another school	☐Yes, I have participated	☐Yes, I have led	☐No
e. Mentoring and/or peer observation and coaching as part of a formal arrangement	☐Yes, I have participated	☐Yes, I have led	☐No
f. Committee or task force focusing on curriculum, instruction, or student assessment	☐Yes, I have participated	☐Yes, I have led	☐No
g. Regularly scheduled discussion or study group	☐Yes, I have participated	☐Yes, I have led	☐No
h. Teacher collaborative or network (such as one organized by an outside agency or over the Internet)	☐Yes, I have participated	☐Yes, I have led	☐No
i. Individual or collaborative research	☐Yes, I have participated	☐Yes, I have led	☐No

j. Independent reading on a regular basis (for example, educational journals, books, or the Internet)	☐Yes, I have participated	☐Yes, I have led	☐No
k. Co-teaching/team teaching	☐Yes, I have participated	☐Yes, I have led	☐No
l. Consultation with a subject specialist	☐Yes, I have participated	☐Yes, I have led	☐No

Consider all of the professional development activities you participated in during the last **two years**. To what extent did you learn about each of the following topics? Mark **one of** the following choices for each line.				
a. How students learn science	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
b. Scientific inquiry and/or technological design	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
c. Content standards in science	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
d. Curricular materials available in science (units, texts)	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
e. Instructional methods for teaching science	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
f. Instructional methods for teaching technological design	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
g. Effective use of laboratory activities in science instruction	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
h. Effective use of information and communication technology (ICT) in science instruction	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
i. Methods for assessing students in science	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all
j. Preparation of students for district and state assessments	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all

k. Strategies for teaching science to students from diverse backgrounds (including English language learners	☐Large extent	☐Moderate extent	☐Small extent	☐Not at all

Do you have special leadership responsibilities for **science education** at your school— for example, responsibilities as a mentor teacher, lead teacher, resource specialist, departmental chair, or master teacher?	
☐Yes	☐No

SECTION 2: TEACHING PRACTICES AND CLASSROOM ENVIRONMENT

Which best describes your role in teaching science to this class?

☐ I do not teach science to this class.

☐ I teach all or most subjects, including science.

☐ The only subject I teach is science.

☐ We team teach, and I have primary responsibility for teaching science.

How many students are in this class?

☐ 15 or fewer	☐ 21–25
☐ 16–18	☐ 26 or more
☐ 19–20	

What portion of the year do students in this class receive science instruction at least once per week?

☐ Never	☐ 3 Quarters per year
☐ 1 Quarter per year	☐ All year
☐ 2 Quarters per year (or 1 Semester)	

About how much time in total do you spend with this class on science instruction in a typical week?	
☐Less than 1 hour	☐5–6.9 hours
☐1–2.9 hours	☐7 hours or more
☐3–4.9 hours	

Is this class considered a gifted, honors, or advanced placement section?	
☐Yes	☐No

Are students assigned to this class by ability?	
☐Yes	☐No

Do you create groups within this class for science instruction on the basis of ability?	
☐Yes	☐No

When you teach science, do you do any of the following? Mark **one of** the following choices for each line.				
a. Use a different set of methods in teaching some students	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
b. Supplement the regular course curriculum with additional material for some students	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
c. Pace my teaching differently for some students	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
d. Have some students engage in different classroom activities	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
e. Set different achievement standards for some student	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent

How often do you use each of the following to assess student progress in science? Mark **one of** the following choices for each line.					
a. Multiple-choice tests	☐Never or hardly ever	☐Less than once a month	☐Once or twice a month	☐Once or twice a week	☐Almost every day
b. Short written responses (e.g., a phrase or sentence)	☐Never or hardly ever	☐Less than once a month	☐Once or twice a month	☐Once or twice a week	☐Almost every day
c. Long written responses (e.g., several sentences or paragraphs)	☐Never or hardly ever	☐Less than once a month	☐Once or twice a month	☐Once or twice a week	☐Almost every day

In this class, about how much time do you spend on each of the following areas of science? Mark **one of** the following choices for each line.				
a. Life science	☐None	☐Little	☐Some	☐A lot
b. Earth and space science	☐None	☐Little	☐Some	☐A lot
c. Physical science	☐None	☐Little	☐Some	☐A lot
d. Engineering and technology	☐None	☐Little	☐Some	☐A lot

About how often do your science students do each of the following? Mark **one** of the following choices for each line.					
a. Read a science textbook	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
b. Read a book or magazine about science	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
c. Work with other students on a science activity or project	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time

d. Prepare a written science report	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
e. Watch a movie, video, or DVD about science	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
f. Watch a science teacher do a science activity	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
g. Do hands-on activities or investigations in science	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
h. Talk about the measurements and results from students' hands-on activities	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
i. Take a science test or quiz	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
j. Identify questions that can be addressed through scientific investigations	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
k. Discuss the kinds of problems that engineers can solve	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
l. Figure out different ways to solve a science problem	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time
m. Present what they have learned about science	☐Never	☐Rarely	☐Sometimes	☐Often	☐All of the time

To what extent do you emphasize each of the following objectives in teaching science to your class? Mark **one** of the following choices for each line.				
a. Increase students' interest in science	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
b. Teach scientific facts and principles	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
c. Teach scientific methods	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
d. Prepare students for further study in science	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
e. Develop inquiry skills	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
f. Develop problem-solving (design) skills	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
g. Develop skills in lab techniques	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
h. Increase awareness of the importance of science in daily life	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
i. Develop systematic observation skills	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
j. Learn about applications of science to environmental issues	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent
k. Develop scientific writing skills	☐Not at all	☐Small extent	☐Moderate extent	☐Large extent

How much of the following instructional materials and other resources does your school system provide you with to teach science to your class? Mark **one** of the following choices for each line.				
a. Science textbooks	☐None	☐Little	☐Some	☐A lot
b. Science magazines and books	☐None	☐Little	☐Some	☐A lot
c. Supplies or equipment for science demonstrations	☐None	☐Little	☐Some	☐A lot

d. Supplies or equipment for science labs	☐None	☐Little	☐Some	☐A lot
e. Space to conduct science labs	☐None	☐Little	☐Some	☐A lot
f. Computers for students' use in class	☐None	☐Little	☐Some	☐A lot
g. Computer labs	☐None	☐Little	☐Some	☐A lot
h. Computers for teachers' use	☐None	☐Little	☐Some	☐A lot
i. Computerized science labs for classroom use	☐None	☐Little	☐Some	☐A lot
j. Audiovisual materials	☐None	☐Little	☐Some	☐A lot
k. Science kits	☐None	☐Little	☐Some	☐A lot
l. Scientific measurement instruments (e.g., telescopes, microscopes, thermometers, or weighing scales)	☐None	☐Little	☐Some	☐A lot

To what extent do you use each of the following technological resources for science instruction? Mark **one** of the following choices for each line.				
a. Desktop computer	☐None	☐Little	☐Some	☐A lot
b. Laptop computer	☐None	☐Little	☐Some	☐A lot
c. Tablet PC	☐None	☐Little	☐Some	☐A lot
d. Digital projector	☐None	☐Little	☐Some	☐A lot
e. CD-ROM	☐None	☐Little	☐Some	☐A lot
f. Online software	☐None	☐Little	☐Some	☐A lot
g. Digital music device (e.g., MP3 player)	☐None	☐Little	☐Some	☐A lot
h. Cable/satellite/ closed-circuit television	☐None	☐Little	☐Some	☐A lot

i. DVD player and DVDs	☐None	☐Little	☐Some	☐A lot
j. Digital camera	☐None	☐Little	☐Some	☐A lot
k. Graphing calculator	☐None	☐Little	☐Some	☐A lot
l. Handheld device (e.g., PDA or smartphone)	☐None	☐Little	☐Some	☐A lot
m. Data collection sensors/probes	☐None	☐Little	☐Some	☐A lot
n. Online course management system	☐None	☐Little	☐Some	☐A lot
o. Digital whiteboard (e.g., Smartboard)	☐None	☐Little	☐Some	☐A lot

Which of the following statements best describes how well your school system provides you with the instructional materials and other resources you need to teach your class?	
☐ I get all the resources I need.	☐ I get some of the resources I need.
☐ I get most of the resources I need.	☐ I don’t get any of the resources I need.

SECTION 3: ATTITUDES TOWARD SCIENCE

Indicate the extent to which you agree or disagree with each the following statements.

	Strongly disagree	Disagree	Not sure	Agree	Strongly Agree
I enjoy science	☐	☐	☐	☐	☐
I like to learn more about science	☐	☐	☐	☐	☐
Most people should understand science because it affects their lives	☐	☐	☐	☐	☐
We live in a better world because of science	☐	☐	☐	☐	☐

Appendix C

Letter of Invitation for School Participants

Greetings! My name is Ryan Summers and I am a doctoral student in the Department of Curriculum and Instruction at the University of Illinois at Champaign-Urbana. The purpose of this letter is to invite your school to participate in a very exciting research study that I will be conducting, under the supervision of Professor Fouad Abd-El-Khalick, this spring. The following sections provide some background on the project and outline the role of your school if you agree to participate.

Educational researchers have been drawn to the study of attitudes as a way of making sense of student preferences and engagement. This focus is rooted in an empirically supported belief that students' attitudes are as important as cognitive variables in influencing achievement, career choices, and use of leisure time. Researchers, both in the United States and internationally, continue to argue that the promotion of favorable attitudes towards science, scientists, and learning science is a viable strategy and goal to enhance student science achievement and encourage them to pursue science studies and careers. This stance draws from numerous studies, which have illustrated a declining trend in students' attitudes toward science as they progress through formal schooling and coupled with ongoing concerns, such as those presented in science education policy directives, of students failing to engage in Science, Technology, Engineering, and Mathematics (STEM) at the post-secondary level.

There is a clear need for continued research into students' attitudes toward science, more specifically there is a dire need for studies that include large-scale data collection. This study will address this need by administering a systematically developed attitude survey to a sample of students, grades 5-12, from a representative sample of schools in Illinois. This project has been endorsed by the Illinois Science Teachers' Association (ISTA) on the premise that it may offer insight into issues intimately connected with science learning and lifelong involvement in the STEM areas.

The cooperation of your school would mean that **one** class section of **XX grade science students** would be invited to complete an online survey about their attitudes toward science. The teacher of the participating class would supervise students while they complete the survey. Participating teachers, due to their critical role in shaping student attitudes, will also be asked to complete a survey. For their participation in this study, teachers will be offered a $25 gift card at the end of the data collection as a token of appreciation.

If you have any questions, or would like to discuss the project in greater detail, please do not hesitate to contact me by phone (618)-214-6710 or via email summers4@illinois.edu.

Appendix D

Teacher Packet to Support US-ASSASS Administration

A STATEWIDE EXAMINATION OF ATTITUDES TOWARD SCIENCE AMONG ILLINOIS STUDENTS IN GRADES 5-12

Participation Overview and Survey Administration Support Guide for Selected Illinois Schools

Participation Guide and Survey Administration Support Guide

CONTENTS

1. STUDY BACKGROUND

Educational researchers have been drawn to the study of attitudes as a way of making sense of student preferences and engagement. This focus is rooted in an empirically supported belief that students' attitudes are as important as cognitive variables in influencing achievement, career choices, and use of leisure time. Researchers, both in the United States and internationally, continue to argue that the promotion of favorable attitudes towards science, scientists, and learning science is a viable strategy and goal. This stance draws from numerous studies which have illustrated a declining trend in students' attitudes toward science as they progress through formal schooling and coupled with ongoing concerns, such as those presented in science education policy directives, of students failing to engage STEM at the post-secondary level.

2. PURPOSE

There is a clear need for continued research into students' attitudes toward science, more specifically there is a dire need for studies that include large-scale data collection. The present study will address this need by administering a systematically developed attitude survey to a statewide sample of precollege students. In an effort to further explore the factors that contribute to students' attitudes toward science, the teacher of each participating class section will also be surveyed. This survey, adapted from a NAEP questionnaire, will ask teachers questions about their teaching practices as well as their access to science teaching materials. Responses collected from students and teachers should help to illustrate the landscape of Illinois students' attitudes toward science and allow for important relationships to be identified.

3. PARTICIPATION OUTLINE

Schools, like yours, were strategically selected across Illinois and invited to participate in this study. Each school contacted was asked to allow one science teacher and their class, a single section from a specified grade level, to complete online surveys. Note that this study includes both a student and a teacher survey. Below is an overview of the study:

3.1 Selection of a science teacher. If multiple teachers lead class sections for the specified grade level, one teacher will need to agree to participate. This teacher will complete the Science Teacher Survey and administer the online student survey to their class.

- Hopefully each participating teacher is interested in the study and enthusiastic about their important role.
- As a token of gratitude, each participating teacher will be gifted a $25 gift card at the end of the study for their help and participation.

3.2 Selection of a class section. If multiple sections of the specified grade level exist at your school, one will need to be selected for participation. This class section should receive some or all science instruction from the science teacher previously selected.

- Please contact the researcher if the class selected to participate has less than 10 students.

3.3 Confirm participation and schedule a time for survey completion. Teachers can reach Ryan Summers, the researcher, by email at summers4@illinois.edu or by phone (618)-214-6710. Instructions for accessing the surveys will be provided at this time.

- Note that all surveys must be completed by XXXX.

3.4 Teachers present consent information. Teachers need to send home the "Parent Information Letter" with students. Copies will be provided.

3.5 Survey implementation. Students will complete the online survey at the scheduled time. Teachers are asked to complete the online Science Teacher Survey within one week of that time.

- Please only allow students of the specified grade to complete the survey.
- Most students should be able to complete the survey in 25 minutes.

3.6 Confirm completion. Teachers need to email the researcher after they and their students have completed the online surveys.

- The researcher will provide any end of data collection information at that time and confirm the details for teacher remuneration.

4. SECURING CONSENT

4.1 Parent information letter

- Teachers will be provided copies of a Parent Information Letter. Please send these home with students in the participating class as soon as possible.
- Students only need to return the letter if their parent or guardian does **not** want them to participate in the study.
- If a student returns a signed letter, the teacher will ensure that the student does not complete the survey.
- Teachers are encouraged, but not required, to help spread awareness of this project in any way possible (e.g., class newsletter, listserv, or website).

4.2 Student assent and teacher consent. This information will be presented at the beginning of the online survey. Students and teachers should understand the following before completing the online survey:

- Participation in the study is voluntary.
- Any responses they provide are protected. Only the researcher, **not** the teacher, will access to students' responses. Also note that no identifying information, such as a name, is collected.
- Any survey item may be skipped if the respondent would prefer not to answer or if the question makes them uncomfortable.

5. ADMINISTERING THE STUDENT SURVEY

5.1 Identify your School Code. Your 5-digit school code is included in the recruitment letter. Both students and teachers will need to enter this code before completing the survey. If you cannot find your code, please contact the researcher.

5.2 Survey access

- Web addresses to the student and teacher survey are provided below. Both a full URL and a simplified Tiny URL are provided. Either address, for each respective survey, can be used. Please note that both surveys require a password, it is also provided below.
- If you would like an electronic link emailed to you, please contact the researcher.

<u>US-ASSASS Student Survey</u>

https://uiuc.qualtrics.com/SE/?SID=SV_4MTQXRJtRjtUcmN

http://tinyurl.com/ILscistudent2014

Student Password: XXXX

<u>Science Teacher Survey</u>

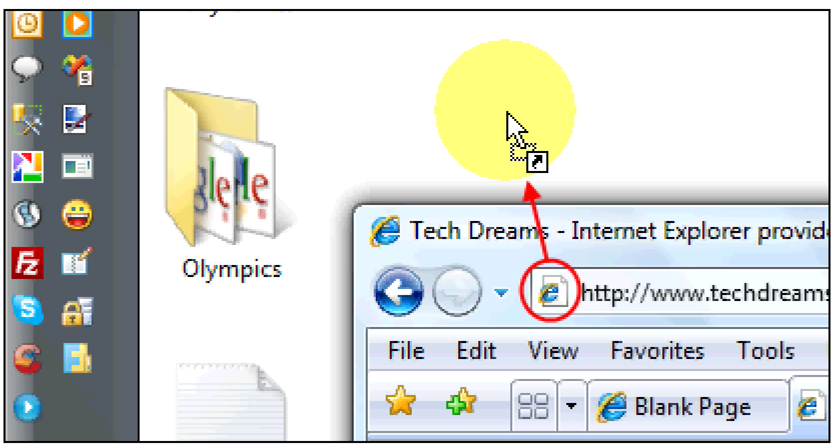
https://uiuc.qualtrics.com/SE/?SID=SV_3pGepyIbdNM9yGp

http://tinyurl.com/ILsciteacher2014

Teacher Password: XXXX

5.3 Strategies for Student Access

- Students can easily navigate to the survey using the Tiny URL address.
- Teachers can also create a desktop shortcut by first navigating to the student survey and then dragging the System icon onto the desktop.



- The System icon can be found on the leftmost side of the location bar.
- It may be easier to create, or share, a desktop shortcut with students, rather than having them enter the web address manually.
- If you have any difficulties accessing either survey, please contact the researcher immediately.

5.4 Important notes about the online platform

- Do not use the back button while taking the online survey. In the event the back button is used, refresh the browser.
- If disconnected from the internet while taking a survey, navigate back to the survey. It may be possible to continue from the point of interruption.

- Please make sure that students completely exit out of the internet browser after completing the survey.

6. FREQUENTLY ASKED QUESTIONS

6.1 Questions about survey access (Both surveys).

- Your School Code is a 5-digit number. It can be found on the recruitment letter you received. The teacher and students will both enter the same number.
- Section 5 contains the web address and password needed to access each survey.

6.2 Questions about background and demographic items (Student Survey).

- Question #7 allows students to select one or more choices to describe themselves.
- It is perfectly understandable if students do not know the answers to some of the background questions (especially questions 9-10).
- Question #14 should be a self-evaluation of the students' own science ability (i.e. they should not need to ask about their grades).

6.3 Questions about terms and vocabulary (Student Survey). For each of the terms below, an acceptable explanation, for the purpose of this survey, is provided.

- Motivate - to encourage or give you a reason to do (something)
- Respect - a feeling or understanding that someone or something is important
- Pursue - to work towards (something)
- Influence - the power to change or affect (someone) in an important way
- Science “concepts” - big ideas in science

7. CONTACT INFORMATION

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University of Illinois Institutional Review Board (IRB)
Email: irb@illinois.edu
Office: 217-333-2670

8. ACKNOWLEDGEMENTS

Professor Fouad Abd-El-Khalick is the responsible principle investigator of this project and the advisor to the researcher, Ryan Summers. His vision, inspiration, and assistance has greatly contributed to this endeavor. Thanks also goes to the Illinois Science Teachers Association (ISTA) for their cooperation and endorsement of this project.

The Student Survey used in this study was developed as part of a large-scale effort to assess students' attitudes toward science. The College of the North Atlantic and the Qatar Foundation are both recognized for their contributions to previous versions of the survey.

Abd-El-Khalick, F., Summers, R., Said, Z., & Culbertson, M. (2015). Development and large-scale validation of an instrument to assess Arabic speaking students' attitudes toward science. Manuscript submitted to the International Journal of Science Education.

Summers, R. (2012). *Development and validation of an instrument to assess precollege Arabic speaking students' attitudes toward science*. Unpublished Master's Thesis, University of Illinois at Urbana-Champaign, Urbana, Illinois.

The National Association of Educational Progress (NAEP) developed many of the items used in the Science Teacher Survey. They are being used with permission.

National Association of Educational Progress (2011). *Science Teacher Questionnaire*. [ONLINE] Available at: https://nces.ed.gov/nationsreportcard/bgquest.aspx. [Last Accessed January 1 2014].

9. ATTACHMENTS

Copies of the following are included for reference purposes:

- Teacher Consent Form
- Student Assent Form
- Parent Information Letter
- Student Survey (US-ASSASS)