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Refinement of a Chemistry Attitude Measure for College Students

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Refinement of a Chemistry Attitude Measure for College Students

by

Xiaoying Xu

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
Department of Chemistry
College of Arts and Sciences
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Date of Approval:
February 1, 2010

Keywords: scale development, reliability, validity, factor analysis, higher education

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Acknowledgements

I would like to thank Dr. Lewis, my major advisor, for her support, guidance and encouragement during the study. Her enthusiastic, patient and persistent attitudes in chemical education program are extremely valuable to overcome possible difficulties. This project could not be done without her.

I need to thank my committee, Drs. Sheryl Li, Robert Dedrick and Santiago Sandi-Urena for their essential contribution in many ways. I also thank Drs. Kromrey and Ferron for conversation on data analysis. I am in gratitude to all group members, Alicia, Bo, Janelle, Karla, Keily, Sachel, Teresa and Ushiri for their friendship and academic advice. I appreciate the instrumental role the chemistry department office staffs, instructors, peer-leaders, test proctors, lab TAs and students played, and the data services the scanning office provided. Special acknowledgement is for Dr. Rick Moog for helpful suggestions on the manuscript.

Finally I would like to acknowledge the steadfast love, inspiration and support from my family: Charley and Feng Cheng.

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Refinement of a Chemistry Attitude Measure for College Students

Xiaoying Xu

ABSTRACT

This work presents the evaluation and refinement of a chemistry attitude measure, Attitude toward the Subject of Chemistry Inventory (ASCI), for college students. The original 20-item and revised eight-item versions of ASCI (V1, V2, V3 and V3.1) were administered to different samples. The evaluation for ASCI had two main foci on the psychometric properties: reliability and validity. Both psychological theory and factor analysis techniques were applied to guide instrument refinement. Evidence for good reliability and validity was established for ASCI V2 score interpretation. The two-factor correlated structure was supported by confirmatory factor analysis. The two subscales, intellectual accessibility and emotional satisfaction, are indicators of cognition and affect components of attitude, and thus we can make good connection with tripartite attitude framework (cognition, affect and behavior) in psychology. As regards to attitude-achievement relationship, other than the well-known aptitude test score, students' attitude played a significant role in predicting final achievement in General Chemistry I course. This work represents the first time in the area of chemical education that a benchmark for scale development was successfully implemented to reconstruct an existing instrument. In addition to showcasing a method for examining validity, a second important result of

this work is to recommend refinements that lead to greater ease of administration while improving validity: this eight item instrument now takes very little time to administer.

Chapter One

Introduction

Assessment is an essential component in education. Results from assessments serve diverse functions for diagnosis, placement, and prediction. Course teachers rely on diverse tests to obtain information of student's mastery of content and other contextual variables such as problem solving and creativity. Although assessment itself is not able to suggest proper instruction, it provides evidence for teachers to judge how effective or ineffective the teaching has worked to accomplish their expected course objectives. Nation-wide exams are mostly used for screening of large candidate pool. For example, most colleges use SAT or ACT scores for college admissions, and GRE scores for graduate admissions. The critical role of educational assessment has produced a burgeoning testing industry with a market growing from \$7 million in 1955 (adjusted to 1998 dollars) to \$263 million in 1997, to somewhere between \$400 million to \$700 million in 2002 (WGBH Educational Foundation, 2002).

There has been a long and vigorous debate among education stakeholders in terms of how to interpret test scores and create education policy (Sedlacek, 2004). The debate has developed into a national concern since the implementation of the No-Child-Left-Behind (NCLB) Act in 2001. Under this influential education reform, all participating states and school districts receiving Title I funds are subject to biennial National Assessment of Educational Progress (NAEP) testing in reading and math for the 4th and 8th grades since 2003 and state testing. All schools need to make adequate yearly progress (AYP) so that

all students can meet the proscribed proficient level by the 2013-2014 school year.

Supporters of NCLB believe the mandated performance standards and emphasis on test scores can improve the quality of public education for all students. Critics focus on the limitations of the tests, potential misinterpretations of test scores, and the unintended consequences of a testing program. For example, is the NAEP measuring the most important aspects of the curriculum? Unfortunately, the love of learning and creativity is not included in the accountability system. Does the testing system motivate teachers to teach students only how to fill in exam bubbles or even to cheat? How does one match up individual state test to NAEP and performance standards? Is it meaningful to compare two groups of students to measure educational progress and AYP? Is it fair to label the schools that didn't meet annual progress in all items as "failures" and penalize them, regardless of the effort those schools have made to improve? Overall, does the testing program result in help for disadvantaged students? These issues, and others, are still debated so frequently in the political arena that it is hard to find a discussion of the relevant issues that moves beyond "sound bites."

While questions such as these will always be difficult to address, a better understanding of educational measurement theory can provide a more nuanced approach to discussions of education policy. The full assortment of measurement theories and practices is beyond the scope of this paper, but the basics are pertinent for all of us who teach chemistry and are aware of the need to improve STEM education outcomes at the national level. For the purpose of assessing both academic achievement and non-cognitive variables such as attitude, the first and most important thing is to find "good" assessments. This study will present one way to proceed with this task.

Why Attitude?

The term “attitude” falls within the purview of “scientific literacy”, which is a central goal of science education. Usually, scientific literacy focuses on the cognitive knowledge dimension, as highlighted by the proposition “the scientifically literate person accurately applies appropriate science concepts, principles, laws, and theories in interacting with his [sic] universe” (Rubba & Anderson, 1978). However, many science educators emphasize that non-cognitive factors such as values and attitudes are important component of science literacy. According to the American Association for the Advancement of Science (AAAS, 1989), “spelling out the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience” is a requirement for a curriculum to be considered as promoting scientific literacy. AAAS places attitudes on an equal footing with knowledge and skills.

Appropriately, there have been many research studies investigating students’ attitudes toward learning science (Custers & Ten Cate, 2002; Dahle, Forsberg, Svanberg-Hard, Wyon, & Hammar, 1997; Gouveiaoliveira, Rodrigues, & Demelo, 1994; Hren et al., 2004; Parke & Coble, 1997). Educational practitioners have developed quality science curricula informed by attitude-related learning theories. Rather than indoctrination, great effort has been taken to develop various innovative programs, which put more emphasis on the problem solving, inquiry-based learning, hand-on activities and computer aided instruction (Ault, 1998; Freedman, 1997; Laws, Rosborough, & Poodry, 1999; Ozmen, 2008; Paris, Yambor, & Packard, 1998; Romance & Vitale, 1992; Shymansky, Yore, & Anderson, 2004; Steele, Medder, & Turner, 2000). The ideal is a curriculum that supports both gains in content knowledge and positive attitudes toward science.

While most practitioners are comfortable creating their own measures of content knowledge, and can recognize a “bad test” or a “bad question” if necessary, fewer are likely to have the necessary skills and comfort level to create and evaluate a measure of attitude. They may turn to existing instruments, and either use them directly or with slight adaptations to fit a particular course. Unfortunately, most existing studies of attitude fail to scrutinize the validity of the instruments they have chosen to use, which can raise questions about study results. Conflicting results, in particular, highlight the importance of using well-characterized instruments, so that the instrument itself can be ruled out as a major source of disagreement. For example, an examination of literature on attitude and chemistry achievement reveals conflicting results (Fowler, 1980; Gutwill, 1998; Lindsay, 2001; Pribyl, Adams, Hoganmiller, & Stevens, 1991; Shibley, Milakofsky, Bender, & Patterson, 2003; Turner & Lindsay, 2003). While some claim a low correlation between attitude and achievement, others claim the two are strongly positively correlated. Is this disagreement an artifact of the way attitude was measured (differently in each case!), or a real difference stemming from the diverse contexts of the studies?

What if, as in the example above, there is no readily available high-quality instrument that has a long history of working well in the relevant context? With much science education research focused on the K12 environment, it is often difficult to find high quality instruments that are appropriate for use in the college science classroom. Creating a high quality instrument is a research project in itself, and one that many faculty would not be interested in undertaking. However, it is possible to take an existing instrument, test it in the desired setting, and quickly optimize it for use. This study seeks to offer an example of carefully modifying an existing attitude instrument to achieve better quality,

while reviewing appropriate strategies for any instrument development process: reliability, validity, factor analysis, and the alignment of any sub-scales with a theoretical framework. These issues must be addressed in deciding whether an assessment can be considered “good.”

The remainder of this chapter will introduce the central concept of attitude in psychology and science education, and create a conceptual framework for this study.

Attitude Concept in Social Psychology

Attitude is one of the most important concepts in social psychology, dating back to the ancient philosophers (Zanna & Rempel, 1988). Attitude has been extensively investigated in the literature. From a behavioral view, attitude is defined as “mental and neural state of readiness to respond, organized through experience, exerting a directive and/or dynamic influence upon the individual’s response to all objects and situations with which it is related” (Allport, 1935, p. 810). In other words, attitudes are considered as tendencies or predispositions to respond to certain stimuli, and the traditional tripartite model comprises three major types of responses: cognitive, affective, and behavioral as illustrated in Fig. 2.1 (Rosenberg & Hovland, 1960, p. 3). Given a particular object about which an attitude exists, “cognition” refers to how people think about the object, i.e. knowledge and beliefs about properties of the object (including both favorable and unfavorable judgments). “Affect” pertains to how people feel about the object (both good and bad feelings), as expressed via physiological activity or overt communication. “Behavior” is overt actions with respect to the object as well as intentions to act (again, both positive and negative actions and intentions). The object of attitude can be something material, such as the game of baseball, or something abstract, such as romantic

love. The research and application of attitude theory from this view highlights the responses to stimuli (such as punishments or rewards), and reinforcement of positive behaviors.

Figure 1.1 Conceptual frameworks for attitude

Since the later era of last century, scholars of cognitive system have competed with the behaviorists, and argued that influence of environmental stimuli on attitude was overemphasized. Instead, attitude is regarded as a node in a dynamic network, as elaborated in theory of cognitive dissonance, self-perception, value-expectancy, self-efficacy, and dissonance-reduction. For example, Bandura believed that attitude concept is used in conjunction with motivation to achieve is self-efficacy in his social cognitive theory (Bandura, 1977). He emphasized the interaction between people, behavior and environments, and that people have the capacity to regulate their motivation, affect and behavior. The theory of cognitive dissonance assumes that a person knows “about himself, about his behavior, and about his surroundings” (Festinger, 1957, p. 9). For example, John knows that he likes smoking, that Mary doesn’t like smoking, and that Mary is his mother. The theory proposes that people have a motivational drive to “reduce dissonance by changing their attitudes, beliefs, and behaviors...” (Festinger, 1957). Possibly, John will change his attitude and stop smoking. Self-perception theory posits

that when people don't have enough internal cues of their own attitude, they may infer their attitude based on external cues and their own previous behaviors (Bem, 1967; Bem & McConnell, 1970).

Eagly & Chaiken reviewed the attitude related theory from different perspective and proposed a working definition. They considered that attitude is “a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor” (Eagly & Chaiken, 1993) p. 1. This definition lies in the root of cognitive theories, because the nature of attitude is evaluation, which is more subjective. In behaviorism system, the nature of attitude is the tendency to respond to environmental stimuli. Eagly & Chaiken further conceptualized the evaluation of attitude as “all classes of evaluative responding, whether overt or covert, or cognitive, affective, or behavioral. Evaluation thus encompasses the evaluative aspects of beliefs and thoughts, feelings and emotions, and intentions and overt behavior” (Eagly & Chaiken, 2007, p. 583). This conceptualization has three necessary components in the tripartite model: cognition, affect, and behavior as in Fig. 1.1, therefore, they called it a neo-tripartite model. By this approach, the neo-tripartite framework may provide a useful link with the previous attitude research and further theory development.

The three-component structure of attitude has been supported by many empirical studies (Bagozzi & Burnkrant, 1979; Breckler, 1984; Eagly & Chaiken, 2007). However, the dimensionality of attitude has been challenged. Some studies apply a unitary model. Petty et al. defined attitude as “evaluation of objects along a dimension from positive to negative” (1997). Attitude here is considered unitary rather than multi-dimensional. This hypothesis is supported in some studies because high correlations were observed among

the three components (Ostrom, 1969). Zanna disagreed with the unitary model. He (1988) emphasized that cognitive and affect are two different components of attitude. The two-component model has been proposed, which does not include the behavior component. The behavior component is often questioned because of the weak prediction power of attitude for prescribed behaviors (Biddle & Mutrie, 2001; Hagger, Chatzisarantis, & Biddle, 2002). Furthermore, it is very hard to create specific behavior items when complicated patterns of behaviors are involved with the objects. The question arises, which model is more appropriate, unitary, two or three-component (McGuire, 1985)? One focus of attitude literature has been on the attitude-behavior relationship and cross-situation behavior consistency issues. Most of the results are suggesting weak relationship and inconsistent behavior pattern (Berg, 1966; Bray, 1950; Kutner, Willkins, & Yarrow, 1952; Lapiere, 1934; Palmer, Burwitz, Dyer, & Spray, 2005; Perlman, Bobak, Steptoe, Rose, & Marmot, 2003). Meta-analysis of 30 attitude-behavior studies yielded no or weak relationships between them (Wicker, 1969). The theory of planned behavior (TPB) is proposed to approach the problem for a better prediction (Fishbein & Ajzen, 1975). In TPB theory, the behavior component is excluded from attitude and considered as another distinct concept; the intention link is added to mediate attitude and behavior. He used attitude and other factors to account for intention, and intention to explain behavior. The TPB theory has been applied in current literatures and the strong correlation between intention and behavior has been supported (Randall & Wolff, 1994; Rivas & Sheeran, 2003). The relationships among various concepts are not the major research purpose in this study but can provide insight for estimation of attitude-related nomological network.

Attitude Concept in Science Education

Historically, learning outcomes are predominantly measured in terms of cognitive factors by standard aptitude test, grade point average (GPA), logical thinking ability and spatial ability (Sedlacek, 2004). However, some researchers argue that the common exams may have little predictive validity for the potential of students from various backgrounds and cultures (Sedlacek, 2004; Sternberg & Williams, 1997; Tracey & Sedlacek, 1984, 1987). Noncognitive factors have been considered as an important learning outcome as early as the Socratic era. Assessment of noncognitive properties, including attitude, motivation, self-efficacy, and learning strategy, can provide unique information to account for students' academic achievement.

Science education is influenced by attitude related theory in various ways. The behavioral theories have been applied to learning and instruction, such as the application of TPB in SER literature (Fishbein & Ajzen, 1975). One teaching approach is called operant conditioning, which focuses on the effect of reinforcement to desirable learning behaviors. One teaching approach from a social cognitive perspective is self-regulation learning (SRL) (Corno & Mandinach, 1983). Since SRL was proposed in the 1980s, it has gained broad popularity in field of science education research and practice. It emphasizes the interactions of cognitive, motivational, and contextual factors and focuses on the effect of environments to help students to become self-regulated learners. SRL has been referred to as the theoretical base in many SER articles (Bong, 2001; Bong & Clark, 1999; Cunningham & Mahoney, 2004; Franko et al., 2008; Gao, Lee, & Harrison, 2008; Hsieh & Schallert, 2008; Margolis & McCabe, 2006; Mills, Pajares, & Herron, 2007; Pajares &

Graham, 1999; Schunk, 1991; Sins, van Joolingen, Savelsbergh, & van Hout-Wolters, 2008; Walker, Greene, & Mansell, 2006).

The science attitude concept is rarely defined clearly and operationalized consistently, possibly due to the diverse theory sources. Researchers started to use attitude in a vague way that will “involve instincts, appetites, habits, emotions, sentiments, opinion, and wishes” (Park & Burgess, 1924). Attitudes toward science (or science attitude) has been defined and dimensionalized in different ways. It may be defined as “the emotional reactions of students towards science... interest, satisfaction, and enjoyment” (Gardner, 1975), which puts emphasis on the affective aspect of attitude. Influenced by TPB, attitude is viewed as “a learned, positive, or negative feeling about science that serves as a convenient summary of a wide variety of beliefs about science” (Koballa & Crawley, 1985), which is more cognitive. These definitions viewed attitude as a unitary concept, whether affective or cognitive component.

In education research literature, science attitude has a more broad meaning. It can include non-cognitive factors, such as self-concept and scientific attitude. Scientific attitude is another different concept which is about “critical mindedness, respect for evidence, objectivity, open-mindedness, and questioning attitude” (Mayer & Richmond, 1982) p. 56. Attitude can be used exchangeable with other terms. For example, the concept of “motivation” is extensively investigated in learning theory and sometimes used as another name of attitude. Motivation is defined as “the internal state that arouses, directs, and sustains goal-related behavior” (Brophy, 2004). Jurisevic et al. used the three-components for the intrinsic motivation, including emotional component of interest, cognitive component of interest and challenge component of internal motivation

(Jurisevic, Glazar, Pucko, & Devetak, 2008). The components of motivation are partially overlapped with the cognitive and affective aspects of attitude. Since the motivation estimate in science learning is more dependent on specific science course and institution, it will not be framework in this study.

It is worth mentioning that the attitude cognitive component is different from the cognitive concept. In education, cognitive test usually means knowledge tests to measure students' mastery of content knowledge or thinking skills. On the contrary, attitude cognitive component is the belief about the knowledge, value and habits of thinking ways, which is the major issue in this study.

More attitude-related terms mostly used in SER and sample test items are listed in Table 1.1. In sum, there is an overlapping part using various terms. The same name could be used to describe different things, and different names could be used for the same thing. Research findings would be more insightful when major concepts are clearly defined and distinguished from other concepts. It is hard to generalize results across studies using instruments based on vague definition and different conceptualization.

Table 1.1.1 Definition of attitude-related concepts with possible test items

Concept	Definition and reference	Possible item
Motivation	"The internal state that arouses, directs, and sustains goal-related behavior". (Brophy, 2004)	"I feel most fulfilled when I am able to solve a difficult problem." (Tuan, Chin, & Shieh, 2005)
Meta-cognition	"the knowledge and regulation of one's own cognitive system" (Brown, 1987)	"I check to see that it (result) agrees with what I expected." (Melanie M. Cooper & Santiago Sandi-Urena, 2009)
Self-efficacy	"Belief in capacity to achieve in a specific domain or task" (Martin & Dowson, 2009) or "judgments of how well one can execute courses of action requires to deal with prospective situations" (Bandura, 1982)	"How well can you interpret chemical equations?" (Uzuntiryaki & Aydin, 2009)
Self-concept	"A cognitive evaluation of one's ability in a domain" (Pintrich & Schunk, 1996) (Bauer, 2005)	"I participate confidently in discussions with school friends about chemical topics."

Table 1.1.2 Definition of science attitude and related concepts with possible test items

Concept	Definition and reference	Possible item
Attitudes toward science	“The emotional reactions of students towards science... Interest, satisfaction, and enjoyment” (Bauer, 2005) (Gardner, 1975)	Science is fascinating and challenging
Scientific attitudes	“critical mindedness, respect for evidence, objectivity, open-mindedness, and questioning attitude” (Mayer & Richmond, 1982)p. 56	I believe my calculation results whatever it makes sense or not.
Value of science	“Problem-solving, science inquiry, thinking, and the relevance of science knowledge in students’ daily lives” (American Association for the Advancement of Science 1993, NRC 1996)	“Learning science is important because I can use it in my daily life.” (Tuan et al., 2005)
Nature of science	“the aims of science, its epistemology, its tactics, its values, its institutional functions, its interactions with society, and its human needs” (Aikenhead, 1973)	Science can provide absolute truth for everything.

Attitude Concept in This Study

This study is focused on the concept of attitude towards the science subject, chemistry.

The investigator is interested to develop an easy-to-use and high quality chemistry attitude instrument for college students. In order to accomplish the goal, it is important to establish the theoretical framework for the instrument design. Moreover, instrument should be able to stand up for empirical evaluation. If the assessment people used to collect data is not based on the proposed theory and there is no evidence in the follow-up studies in terms of reliability and validity, it is hard to compare the results based on different attitude assessments. Just as Doran and colleagues pointed out:

... [T]hat ambiguity of terms and quality of instruments are two serious problems facing those interested in assessing attitudes to science. The lack of a theoretical base has been cited in nearly all cases as a hindrance to assessment. Furthermore, the lack of empirical support for most of the existing instruments has exacerbated the situation (Doran, Lawrenz, & Helgeson, 1994, p. 428).

This study does not have a specific theory to base on. Instead, the investigator agrees with Eagly et al in the use of the cognitive perspective of attitude concept, because learning is a complicated and interactive process. Derived from Eagly's working definition, science attitude is defined as the psychological tendency through evaluating the subject of science in general with some degree of favor or disfavor.

From this definition, the investigator is creating a pragmatic model including two attitude components from the neo-tripartite model: cognition and affect. Although definitions by Gardner and Petty view attitude as a unitary concept, the investigator would argue for the retaining a two-component framework in the area of science education. First, educators typically care about both cognitive and affective issues. Just as a person's attitude toward ice cream has a cognitive component (unhealthy, not a part of a balanced diet) and an affective component (yummy!), students often say science is challenging (cognitive) yet interesting (affective). The affective and cognitive components of attitude remain conceptually distinct. It is helpful to know students' answers to both kinds of questions, rather than lumping them together to get a single attitude score or simply gathering information regarding one or the other.

The investigator would also argue that, when the science subject in general is the object of attitude, instruments that exclude the behavior component are the best for many research purposes. Although attitude can be inferred from behavior, behavior is not at the same level of abstraction as cognition and emotion. In that sense, concrete items about behavior on an instrument can actually make it harder for respondents to focus on accurate reporting for more abstract items relating to emotions or beliefs. Also, since desirable behavior patterns can vary dramatically for instructional settings, it is hard to

create behavioral items suitable for different situations in order to estimate attitudinal differences. Furthermore, when attitude is to be treated as an indicator of future behavior, as the Theory of Planned Behavior recommends, excluding behavior from the attitude study is meaningful (Fishbein & Ajzen, 1975). Therefore, the investigator decided to use the two-component framework.

The two-component model including the cognitive and affective aspects has been supported by confirmatory factor analysis (CFA) in the SER literature (González, 1992; Mohsin, 1990; Oppenheim, 1992). In the instrument which was developed in 2000 to assess student attitude toward physical education with reliability and validity evidence, the authors found two primary factors, enjoyment and perceived usefulness, which are congruent with the affective and cognitive aspects of the two component framework (Subramaniam & Silverman, 2000, 2007).

In sum, the two component (cognition and affect) attitude model will be used as a framework to guide this instrument development process. In the following thesis, Chapter Two summarizes existing attitude measurements; Chapter Three introduces technique background about psychometric quality, including reliability and validity estimate; Chapter Four is the method section for this study; Chapters Five and Six are results and discussion from the administration of original and revised ASCI; at last, Chapter Seven summarizes the whole study.

Chapter Two

Literature Review

This chapter starts with literature review of the typical attitude scales. Then the previous attempts to measure attitude towards science and chemistry are discussed.

Typical Attitude Measurement Scales

Appropriate assessments of science attitude are important for diverse research purpose, such as evaluation of course effect and attitude theory development. The concept of “attitude toward science” is elusive and cannot be measured directly, at least not as directly as the way to measure speed using a stopwatch. Indicators from responses to carefully designed statements are often used to measure abstract constructs indirectly. Qualitative and quantitative methods have been used to measure students’ attitudes toward science. Because qualitative approaches including observations and interviews are time consuming and not applicable to classroom use, this study focuses on the quantitative methods using psychometric survey. Single indicator attitude survey is often used, for example, how do you describe your liking of science on a 1-10 scale? Critiques of single indicator survey are the lack of reliability estimate (Straus & Wauchope, 1992). A composite score based on multiple indicators is better than a single indicator in terms of reliability and validity evidence from a psychometric perspective. According to the organization of test items, there are four typical different attitudes scales, including Thurstone, Likert, Guttman, and semantic differential (Table 2.1). Thurstone and Guttman scales call for answers of agree or disagree, so the responses are dichotomous.

Likert and Semantic differential scales ask participants to choose the position they locate usually on a five or seven-point scale.

Table 2.1 Description of four typical attitude measurement scales

Scale	Description	Sample test item
Guttman scale (DeVellis, 2003)	“a subset of the survey items having binary answers scale if they can be ranked in some order so that, for a rational respondent, the response pattern can be captured by a single index on that ordered scale.” Agreement with item 3 implies agreement with items of lower rank order: 1 and 2.	To what level the attitude is toward immigrants: Are you willing to permit immigrants to live (Least extreme) 1 in your country? 2. in your community? 3. in your neighborhoods? 4. next door to you? (Most extreme) 5. in your family (marry your child)? (answer Y/N to each one)
Thurstone Scale (Thurstone, 1928)	The statements followed by binary answer (e.g. agree or disagree) should constitute nearly an evenly graduated series of scale values (e.g. from very necessary to useless).	Happiness has ----- to do with achieving educational or material goal. 1 nothing 2 something 3. a lot (answer Y/N to each one)
Likert Scale (Likert, 1932)	respondents specify their level of agreement to a declarative statement. (could range from strongly disagree to strongly agree in a 5 likert)	Science knowledge is important in my daily life. 1 strongly disagree 2 disagree 3 Neutral 4agree 5strongly agree (pick one from the five options)
Semantic differential Scale (Snider & Osgood, 1969)	The respondent is asked to choose where his or her position lies, on a scale between bipolar adjectives	Learning chemistry is: Valuable- - - - - Worthless. (pick one from the seven positions)

Quality Evaluation for Existing Science Attitude Instruments

Many science attitude instruments exist. Fortunately, meta-analysis can be utilized to systematically evaluate the quality of these instruments, and, when published meta-analyses exist, they are a tremendous help for instrument selection. For example, Munby reviewed 56 instruments for their psychometric and conceptual evidence (1983), and recommended seven instruments. However, his selection criteria did not put much weight on validity and item content issues. More recently, Blalock developed a scoring rubric to rate the 66 instruments published in 150 peer-reviewed articles during 1935 ~ 2003 (Blalock et al., 2008). The rating rubric includes five major categories:

1) Theoretical background for instrument development (3 pts)

- 2) Reliability: internal consistency, test–retest, and standard error of measurement (9 pts)
- 3) Validity: content, discriminant, congruent, contrasting groups, and factor analyses (9 pts)
- 4) Dimensionality (6 pts)
- 5) Development and usage (1 pt)

This rubric covered most aspects of psychometric properties. A high-quality instrument should hold to current measurement standards, and score high on a rubric like this.

However, a high score on this rubric does not necessarily guarantee a high quality instrument, because Blalock's rubric is not harsh but relatively lenient. Some important issues were not accounted for in his rating rubric, such as the influence of missing data, descriptive analysis and normality check to perform factor analysis. Moreover, there are different factor analysis techniques which serve different research purposes and should be used consistently. At this time, the investigator use Blalock's rubric for estimate the existing attitude instruments.

The average score for the 66 instruments was reported to be 9.5 out of 28. Scores ranged from 0 to 22, with a standard deviation of 4.9. Twenty-four instruments scored 7 or below. At the higher end, only two instruments scored higher than 20 points. Blalock's conclusion is that the general quality of instruments is quite low. Most of them lack the psychometric aspects, including the use of explicit theory base, report of reliability and validity evidence. Researchers have created and are still continuing to create new attitude instruments on their own resulting in the overall poor psychometric quality instead of revising and improving an existing one. Most instruments have never been used in follow-up studies. When an old one is used, very little attention was paid about its quality. Even the most extensively used one, Scientific Attitude Inventory (only scored 10 out of

28), which was even criticized for the revised form (Lichtenstein et al., 2008). Although psychometrics property has long been well honored, science attitude instruments did not exhibit an obvious pattern of quality improvement with years.

There are various reasons to possibly account for this unsatisfactory situation. One is that test validation is a long and complicated process, which always involves mixed research methods and crosses multiple disciplines like psychology, psychometrics, learning theory, inferential statistics, pedagogy, and subject content knowledge. Another reason is that in most graduate programs students are poorly trained in measurement-related fields and there is a shortage of measurement professionals to take the responsibility of test score validation. As Pedhazur and Schmelkin (1991) observed, “most programs in sociobehavioral sciences, especially doctoral programs, require a modicum of exposure to statistics and research design, few seem to require the same where measurement is concerned” (p. 2).

Proper description and reference of theory background is the first and important step in guiding instrument development, because it is the starting point to clearly define what kind of attitude concept the instrument is really intended to measure and the dimensionality of the concept. The developers tended to bring more related constructs to an attitude questionnaire without careful definition and discrimination, such as self-concept, self-efficacy, interest, learning strategy, motivation, behavior of effort, and learning goals, value of science and so on. So the survey itself is a network of related constructs rather than components of one major construct (more descriptions about these terms are in Table 1.1). The intension and dimensionality of the concept should be consistently applied to create pilot item pool. If an instrument has more than one

dimension, it is problematic to use it as if it is one-dimensional by using a single composite score (Neuberg, West, Judice, & Thompson, 1997).

Review of literature revealed more instrument development problems. It is desirable to have items designed to load on one thing conceptually not the others (Netemeyer, Bearden, & Sharma). If concepts are not discriminated from one another, it is hard to create items and make interpretations using sum scores. For example, the item “I feel proud of my ability” could be an indicator of constructs like self confidence, self-concept, self-efficacy, self-esteem or self-respect on different instruments. However, an item like this is not appropriate to be used for different concepts on one instrument.

Moreover, it is improper to add items representing different objects together to create one composite score. For example, it doesn’t make sense to have the factor score for items “I like the banana” and “I like computer”. Science attitudes surveys tend to have items representing various attitude objects including classroom environment, labs, test anxiety, teachers and scientists, which seem inclusive and comprehensive. In this case, it is hard to compare the composite score across situations with different backgrounds because students may have different understanding of specific objects like labs or teachers. The importance of a single attitude object is illustrated as follows:

An attitude instrument yields a score. If this score is to be meaningful, it should faithfully reflect the respondent’s position on some well-defined continuum. For this to happen, the items within the scale must all be related to a single attitude object. A disparate collection of items, reflecting attitude towards a wide variety of attitude object, does not constitute a scale, and cannot yield a meaningful score (Gardner, 1975: 12).

Psychometric evidence should be reported when using instruments, and the strategies to perform statistics analysis should be carefully selected to serve the research purpose.

Unfortunately that is very rare. Methodological problems have been found in the science or chemistry attitude measurements. Most articles never justify their strategies and just report the “best” evidence after trying different strategies, or overuse the default option provided by the statistical software, hence cannot stand against the critics (Cronkhite & Liska, 1980). For example, test-retest reliability requires two administrations of the same instrument for the same people after a period of time, and should not be used for the different test forms or different samples. Another issue is, the internal consistency measured by Cronbach's alpha for the whole instrument doesn't lend support to unidimensionality and the use of the total score (Gardner, 1995). This means, Cronbach's alpha and factor score should be reported for each scale rather than overall instrument. For construct validity, many researchers didn't justify why they used CFA rather than EFA, why PCA, why oblique rotation rather than orthogonal rotation, how the number of factors was decided to extract and so on. Furthermore, when factor analysis yields a model of different item loading patterns from the proposed model, usually no explanations or suggestions were given.

Because of various reasons, the average score for the overall instrument is so low. To make the findings based on instruments more acceptable and generalizable for other scientists and practitioners, it is important to establish evidence for the responses each time when using the instrument. In depth discussions about the techniques to evaluate psychometric quality such as factor analysis will be discussed in Chapter Three.

Quality Evaluation for Existing Chemistry Attitude Instruments

The question arises, is the situation of science attitude instruments similar to chemistry-specific instruments? Several chemistry attitude instruments have been developed and reported specifically (Barbera, Adams, Wieman, & Perkins, 2008; Bauer, 2005, 2008; Leavers, 1975; S. E. Lewis, Shaw, Heitz, & Webster, 2009; Walczak & Walczak, 2009). They are asking students to answer questions on different attitude related construct, such as attitude towards science, self-concept, metacognition, cognitive expectations toward chemistry. When Blalock's rubric is applied to these reports (Table 2.2), overall the psychometric quality is better than for the science attitude measurements but still unsatisfactory. The only two instruments for which detailed factor analysis and factor scores were reported were the Attitude toward the Subject of Chemistry Inventory (ASCI) (Bauer, 2008) and the Chemistry Self-concept Inventory (SCI) (Bauer, 2005). SCI has excellent evidence for reliability and validity, scoring the highest of all the instruments, but it is aligned with a particular sub-construct of attitude rather than with the general attitude concept discussed above as our target. ASCI, which is more aligned with the general attitude concept, scored the second highest, with 18 out of 28 points, significantly higher than the average of the 66 science attitude instruments but still lower than desirable. In addition, the ASCI subscales were not captured well via factor analysis, indicating a potential problem with the underlying fit between the instrument and its theoretical framework.

Table 2.2 Score for chemistry attitude instruments on JCE according to Blalock's rubric

Survey	Study population	Theoretic base	Reliability	Validity	Dimensionality	Development and usage	Score
<i>Highest possible</i>	<i>points</i>	3	9 ^a	9 ^b	6	1	28
Opinion survey (Leavers, 1975)	n=130, college chemistry class students (for nonscientist)	0	0	0	0	0	0
Attitudes toward Laboratories (Chatterjee, Williamson, McCann, & Peck, 2009)	n=703, college chemistry laboratory students	3	0	3	0	0	6
VOSTS (Walczak & Walczak, 2009)	n=37, college chemistry students in a non-science major's course	3	0	6	0	1	10
CHEMX (Grove & Bretz, 2007)	n =157, college chemistry faculty	3	3	9	0	1	16
CLASS (Barbera et al., 2008)	n>500, college student in general chemistry	3	3	9	0	1	16
MCAI (M. M. Cooper & S. Sandi-Urena, 2009)	N=537, college students, intact class in chemistry lab	3	3	9	0	1	16
ASCI (Bauer, 2008)	n=379, college chemistry lab	3	2	9	3	1	18
Self-Concept Inventory (Bauer, 2005)	N=379, students in a non-science major's college chemistry course	3	5	9	6	1	24

^a Internal consistency, test-re-test and standard error of measurement

^b Content, discriminant, congruent, contrasting groups, FA

The investigator found that the Attitude toward the Subject of Chemistry Inventory (ASCI) (Bauer, 2008) was a good candidate to for this study for several reasons. Overall the ASCI is a high-quality instrument, and it is informative for other teachers' implementation in chemistry classroom. Firstly, the test purpose is clearly stated, to measure the attitude towards chemistry in general, not the specific course or instructor. The attitude concept was properly defined and distinguished with other variables like belief, self-concept and scientific habits. Secondly, it is designed in the 7-point semantic differential format: "Students position themselves on a seven-point scale between two polar adjectives, in reference to how they feel about the attitude object 'chemistry'." One sample item asks students to rate their position from "exciting" to "boring". It is the

easiest format to answer and intuitive to interpret. Twenty pairs of objectives are carefully selected to tap students' attitudinal status towards a single object of chemistry in general after a cognitive interview. Furthermore, ASCI provided an acceptable internal consistency and test-retest reliability. Construct validity was supported by correlation of attitude scores with other concepts, contrasting groups, discriminate and factor analysis. The items were grouped into five subscales: interest and utility (including five items), fear (one item), emotional satisfaction (four items), intellectual accessibility (five items), and anxiety producing (four items) according to factor analysis results. Finally, ASCI comes with guidelines for administration, scoring, and score interpretation for instructors and other researchers.

However, there is space for improvement. The factors emerging from factor analysis based on the 379 responses from the first semester of general chemistry laboratories did not reflect the subscales the authors claimed. Actually, only three factors emerged from factor analysis. The Fear subscale only has one item, which did not load well on other factors, so it cannot be considered as a factor. The Emotional Satisfaction items loads on multiple factors, so the authors used the word "Set" rather than a "Factor". Moreover, the Interest and Utility subscale possibly contains two different concepts. Because procedures like confirmatory factory analysis (CFA) was not performed, there is no report of measurement error.

Another reason for choosing ASCI is the attitude object for ASCI is chemistry in general, rather than specific curriculum or lab. This study is interested in developing an attitude measurement which can yield reliable and valid scores for the college students toward chemistry in general in order to fit the different universities or curriculums. If items are

about specific contexts like cooperative learning for college chemistry, students could have different understanding dependent on their course settings, which will lead to different item loading pattern for different populations. By using chemistry in general, the investigator expected that assessment would hold valid for diverse college chemistry course situations.

The study of the Attitude Toward Science in School Assessment (ATSSA) (Germann, 1988), which scored the highest of all the science attitude instruments on Blalock's rubric, inspired us to use factor analysis to refine an instrument. In its pilot test, ATSSA included 24 items which loaded on 5 factors from exploratory factor analysis (EFA). The developer concluded that the first factor, comprising 14 items, was consistent with the desired construct but the other 10 items dealt with more specific objects like testing and labs. In a follow-up administration of a shortened version of the instrument, the one-component structure was supported, and this became the final version of the instrument. In addition to proposing and administering a revised version of ASCI, we will be able to utilize confirmatory factor analysis to obtain an estimate of the model fit and information about sources of measurement error, which was not easy to do at the time ATSSA was developed.

In this study, because the investigator wanted to capture two subscales (to align with two components of the general theory of the attitude concept), the original and revised ASCI (V2), comprising items from the original 20-item ASCI, were proposed for college chemistry students. It is expected that the revised ASCI would yield responses with two-component structure and map into our two-component theoretical framework, and thus improve the construct validity. The technique backgrounds for scale reconstruction and

quality evaluation, however, deserves further comment and will be discussed in the next chapter.

This study will attempt to address three specific research questions.

Research questions

Question 1

How is psychometric quality evaluation for the responses from ASCI in terms of reliability and validity?

Question 2

How can ASCI be modified based on factor analysis and theoretical framework?

Question 3

How is psychometric quality evaluation for the responses from revised ASCI versions in terms of reliability and validity?

Chapter Three

Methodological Background

This chapter presents the methodological background about psychometric quality which is necessary to understand what is coming in the next chapters. It starts with the proposed instrument development processes, and then elaborates the two major issues for instrument development: reliability and validity. Then several factor analysis techniques are discussed.

Proposed Instrument Development Processes

The development of a “good” instrument from scratch involves a long, cyclic process. The overall instrument development process is illustrated in Fig. 3.1. The first stage (left part) involves the qualitative process. It includes the identification of test purpose: what is the concept the test is designed to measure? The construct should be clearly defined along with content domain and dimensionality. After the test blueprint or table of specification is created, it is good to generate initial item pool. Ask an expert and layperson to review items to identify and discuss any content issues related to these items: What is the scale of measurement for these items? What is your reaction to the analyses using this scale in terms of content validity and face validity? Revision will be made to make the pilot test items according to the feedback. The second stage (the right part) mainly involves the quantitative psychometric process. Pilot test is given to the representative samples to examine the responses in terms of reliability, validity, utility and practicality. Revise or delete the items associated with responses of poor psychometric quality. Continue to conduct studies until the revised test is functioning well. The last step is to develop

guidelines for administration, scoring, and interpreting the scores for further study and other researchers.

Figure 3.1 Instrument development processes (from Dedrick’s class note)

As is discussed in the previous chapter, ASCI did a good job in term of qualitative part. Starting from ASCI has the advantage of skipping the most time-consuming part of the first stage. The second stage, the quantitative part especially on reliability and validity, is the key point for this study and will be discussed in more details below.

Reliability

The most important issues for a “good” instrument pertain to the reliability of the scores (Is it providing consistent results?) and validity (Is it measuring what the developer intended to measure?). The conception of reliability dates back to 1904 (Spearman, 1904). Spearman first proposed the concept and the ways to evaluate the degree of score reliability. Reliability is important because no score can be perfectly reliable even in the natural science area. As stated by Pedhazur, “the presence of measurement errors in behavioral research is the rule rather than the exception” and “reliabilities of many

measures used in the behavioral sciences are, at best, moderate” (Pedhazur, 1997, p. 172).

If a measurement yields totally random scores, the scores are not reliable and cannot measure anything. The scores with poor reliability cannot be valid. And the findings based on the unreliable measured scores are questionable. Wilkinson and the APA Task Force on Statistical Inference emphasized the importance of reporting the reliability estimate:

It is important to remember that a test is not reliable or unreliable... Thus, authors should provide reliability coefficients of the scores for the data being analyzed even when the focus of their research is not psychometric. .. Interpreting the size of observed effects requires an assessment of the reliability of the scores. (Wilkinson, 1999, p. 596)

Reliability estimate has different angles such as test-retest reliability and internal consistency. Test-retest reliability means that the same individual should score similarly on one instrument at different times if other environmental factors are controlled.

However, people usually only take the instrument once, therefore test-retest reliability is hard to estimate. Another aspect of reliability is internal consistency, which can be measured by Cronbach’s alpha to estimate the level that all items hold together and consistently measure one construct. Cronbach’s alpha is the mostly frequently reported reliability estimate because of its convenience of single administration. It is calculated using Equation 3.1:

$$\alpha = \left[\frac{K}{K-1} \right] * [1 - (\sum \delta_k^2) / \delta_{\text{total}}^2] \quad \text{Equation 3.1}$$

Where K is the number of items, $\sum \delta_k^2$ is the sum of the K individual item score variance and δ_{total}^2 is the variance in the total score. Cronbach’s alpha can range from negative

infinity to +1 mathematically. The closer it is to +1, the more reliable the total score is. When it is close to +1, the item scores are positively linearly correlated with each other and the total score. Being greater than .7 is considered to be acceptable reliability (Nunnally, 1978). If the alpha is significantly less than 0, the items may be perfectly correlated with each other but with mixed signs (positive or negative relation mixed), and thus makes Crohbach' alpha horribly low. If the alpha is close to 0, the items scores are uncorrelated.

Validity

Reliability is only one part of the instrument validity but not sufficient (Moss, 1994). If the scores are not reliable, they cannot be considered to be valid unless the instrument is designed to measure nothing (Bruce Thompson, 2003). An instance of validity is, if I step on a scale three times in a day, and it reads 0, 100 and 200, then I am really not sure what is to measure. Even when good internal consistency estimate is achieved, it is not sufficient for validity of one construct and use of total score. A good example was presented by Gardner (1995) as shown in Fig 3.2. Assume we have nine items in the instrument. For situation 1, items produce random and not correlated results, suggesting poor internal consistency and poor dimensionality. For situation 3, all items are highly correlated with each other, which indicate good internal consistency and one dimension. In situation 2, nine items are divided into 3 distinct groups. In this situation, overall internal consistency is good, items within groups are correlated. Since three factors are distinct and uncorrelated mathematically, it is better to report factor score on each scale rather than a total score. It is not meaningful to add an apple, a hotdog and a notebook together. When the test has three dimensions like in situation 2, validity of using a single

composite score is not established. Instead, internal consistency and factor score should also be reported for each scale rather than for the whole instrument.

Figure 3.2 Internal consistency and unidimensionality (Gardner, 1995)

Validity is about the degree to which scores from a measurement measure what it purports to measure. Score interpretation will affect the following decision and action, which is also a validity concern. For example, if I stand on the scale and it reads 200, does that mean I am IQ 200? Does that mean I am a smart student? Shall I celebrate for that? Here is a list of representative selection of more elaborate definitions and standards for validity.

[Validity is] the degree to which inferences from the results of the assessment of the knowledge, skills, attitudes, and behaviors of the evaluatee are trustworthy.

(The joint committee on standards for educational evaluation, 2007, p. 179)

The key validity issues in future assessment are the same as they have always been, ... Validity is an integrated evaluative judgment of the degree to which empirical evidence and theoretical rationale supports the adequacy and

appropriateness of inference and actions based on test scores or other models of assessment (S. Messick, 1989).

[Validity refers to] “the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests. Validity is, therefore, the most fundamental consideration in developing and evaluating tests. The process of validation involves accumulating evidence to provide a sound scientific basis for the proposed score interpretations. It is the interpretations of test scores required by proposed uses that are evaluated, not the test itself. When test scores are used or interpreted in more than one way, each intended interpretation must be validated” (AERA, APA, & NCME, 1999, p. 9).

Validation speaks to a diverse and potentially critical audience; the arguments must link concepts, evidence, social and personal consequences, and values...

Strong construct validation is best guided by the phrase ‘plausible rival hypotheses’... The bottom line is that validators have the obligation to review whether a practice has appropriate consequences for individuals and institutions, an especially to guard against adverse consequences. (L. J. Cronbach, 1988)

There are common features running through these validity definitions. Validity is a property of test scores rather than the test itself (AERA, APA, & NCME, 1999, p. 9).

Both empirical evidence and theoretical rationale need to be considered in terms of validity (S. Messick, 1989). Psychometric evaluation of an instrument score can verify the theory related to the construct. They suggest modification for the theory underlying the construct when necessary. They indicate modification of the instrument for better psychometric quality. It is worthy to mention that test scores can be valid for one purpose

but not for another. Validity is also the process to justify the inference based on the test scores. Cronbach further emphasizes the plausibility against rival hypotheses (L. J. Cronbach, 1988).

There are various aspects of validity discussed in literature, such as content validity, factorial validity, convergent validity, and criterion-related validity etc. Content validity involves the process of developing and reviewing the content of the instrument by the panel of subject-matter experts about clarity and representative of construct domain. This is a fundamental property of a test, but it is arbitrary and not dependent on the test scores. Factorial validity refers to the loadings of test item scores on the assumed factors from internal structure analysis, and thus provides strong evidence of validity. Convergent validity means the results of one specific construct from different methods should be similar. Discriminant validity means the results of different constructs should be different. Criterion-related validity includes predictive (purpose of measurement, predict later performance) and concurrent validity (correlation with other related constructs measured at the same time). Nomological network pertains to empirical evidence to build “lawful” sets of relationships between the measured construct and other theoretical concepts or observable properties in order to make a case for the existence of the construct (Lee J. Cronbach & Meehl, 1955). They used the word “law” to describe the expected relationship among observable properties or theoretical constructs. They proposed that “to make something is” scientifically means to set forth the laws in which it occurs. My understanding is, a robust nomological network grounds a measured construct in a web of proposed relationships, the strengths and directions of which, as determined empirically,

match theoretical predictions. Accordingly, correlational and experimental analyses are the most-used techniques to support nomological network building.

All aspects of validity can fall under one overarching category: construct validity.

Construct validity is considered as “a mutual verification of the measuring instrument and the theory of the construct it is meant to measure. More accurately, it reflects a verification of the inferences and interpretations to be drawn from the test scores and a corresponding modification (if so indicated) of the instrument and/or the theory underlying the construct” (Angoff, 1988). Similarly, construct validity is defined as “the unifying concept of validity that integrates criterion and content considerations into a common framework for testing rational hypotheses about theoretically relevant relationships” (Samuel Messick, 1980). Cronbach and Meehl first proposed the factor analysis as a useful computational tool since “a matrix of intercorrelations often points out profitable ways of dividing the construct into more meaningful part” (Lee J. Cronbach & Meehl, 1955).

The Standards for Educational and Psychological Tests (SEPT) recommended the report of internal structure from a test score, and dimensionality, which is supported by statistical technique like factor analysis.

If the rationale for a test use or interpretation depends on premises about the relationships among parts of the test, evidence concerning the internal structure of the test should be provided.... It might be claimed, for example, that a test is essentially unidimensional. Such a claim could be supported by a multivariate statistical analysis, such as factor analysis, showing that the score variability

attributable to one major dimension was much greater than score variability attributable to any other identified dimension. When a test provides more than one score, the interrelationships of those scores should be shown to be consistent with the construct(s) being assessed. (Standard 1.11)

Regardless of the endorsements from the most eminent scientists like Cronbach and SEPT standard mentioned above, factor analysis has encountered critics, as Cronkhite and Liska noted:

Apparently, it is so easy to find semantic scales which seem relevant to [information] source, so easy to name or describe potential/hypothetical sources, so easy to capture college students to use the scales to relate the sources, so easy to submit those ratings to factor analysis, so much fun to name the factors when one's research assistant returns with the computer printout, and so rewarding to have a guaranteed publication with no fear of nonsignificant results that researchers, once exposed to the pleasures of the factor analytic approach, rapidly become addicted to it. (Cronkhite & Liska, 1980, p. 102)

It is important to keep these critics in mind when factor analysis is used for data analysis and interpretation. Factor analytic approach should not be misused as an advantage over other statistics approaches. It should not have any privilege for publication purpose without careful judgment. To make good use of factor analysis, the research design and analysis strategy should be carefully selected and justified, rather than just trying different strategies and reporting the best-wanted results. Several methodological problems have been mentioned in previous chapter. In the following sections, the factor analysis approach will be discussed in more details.

Factor Analysis

Factor analysis is widely used to analyze scores from an instrument. It seeks to discover the simple pattern in the relationship among the observed variables. For example, if an instrument has 20 items grouped into 2 scales and items within each scale are highly correlated, it is reasonable to report 2 factor scores summing the grouping items, rather than report all the 20 items. It makes the interpretation simple and easy!

Sample Size

Usually factor analysis requires a large sample size. However, it is not clear how large is enough. Some rules of thumb can be used at hand (Hogarty, Hines, Kromrey, Ferron, & Mumford, 2005; MacCallum, Widaman, Preacher, & Hong, 2001; Marsh & Balla, 1994; Marsh, Balla, & McDonald, 1988; Shevlin & Miles, 1998). Unfortunately, there are serious drawbacks to such guidelines. One problem is that these recommendations vary dramatically. For instance, Gorsuch (1983) suggested a ratio of five participants per measured variable and that the sample size never be less than 100. In contrast, Nunnally (1978) and Everitt (1975) proposed ratios of 10 to 1. More importantly, recent research has suggested that such guidelines are not sufficiently sensitive to a variety of important characteristics of the data (MacCallum et al., 1999; Velicer & Fava, 1998). The primary limitation of such guidelines is that adequate sample size is not a function of the number of measured variables per se but is instead influenced by the extent to which factors are overdetermined and the level of the communalities of the measured variables. When each common factor is overdetermined (i.e., at least three or four measured variables represent each common factor) and the communalities are high (i.e., an average of .70 or higher), accurate estimates of population parameters can be obtained with samples as small as 100

(MacCallum et al., 1999). However, under more moderate conditions a sample size of at least 200 might be needed; when these conditions are poor it is possible that samples as large as 400 to 800 might not be sufficient (Fabrigar, Wegener, MacCallum, & Strahan, 1999).

EFA or PCA

EFA and PCA (principal component analysis) are similar eigenvector-based multivariate analysis methods with the only difference in the regression direction. The different model of EFA and PCA is illustrated in Fig. 3.3 (from Ferron Statistics classnote). EFA is used when a researcher wishes to identify a set of latent constructs underlying a battery of measured variables. The primary purpose of EFA is to arrive at a more parsimonious conceptual understanding of a set of measured variables. Before using EFA, a researcher should carefully consider if this is a goal of the research project (Fabrigar et al., 1999). In PCA, the component variables are combinative of all items, and they don't reflect latent variables as in EFA. Therefore, there are clear conceptual distinctions between PCA and EFA. Although these approaches often produce similar results, this is not true in certain contexts. When the goal of the analysis is to identify latent constructs underlying measured variables, it is more sensible to use EFA than PCA (Cattell, 1978; Gorsuch, 1983; McDonald, 1985; Mulaik, 1972; (Fabrigar et al., 1999).

Figure 3.3 PCA and EFA model

EFA or CFA

While both EFA and CFA provide parameter estimate including item loadings, CFA offers more advantages over EFA at the instrument validation stage. It is even more appropriate when the instrument is designed based on a theoretical and conceptual model. In this situation, the CFA preference is endorsed by measurement professionals, which is embodied in statements, that “current think[ing] on construct validation argues that the most rigorous test of factorial structure is through CFA techniques” (Greenbaum & Dedrick, 1998), and that “CFA is a commonly accepted method to test/confirm dimensionality” (Netemeyer et al., 2003). CFA can provide fit indexes to examine the overall goodness of fit of a model which EFA cannot. Also it offers information about the source of measurement error and how the model fit can be improved by modifying the model.

EFA and CFA models are illustrated in Fig. 3.4. For the EFA, all items are allowed to load on all the factors. The term “factor pattern coefficient” is consistently used for the weight (or standard regression coefficient) of each item on its factors. It is given in the factor pattern coefficient (matrix P). The single correlation coefficient between the item and the factor score is presented in the “factor structure coefficient” (matrix S). The two

sets of coefficients are identical in number for orthogonal rotation when factor correlation is 0 (so factor correlation matrix R is identity matrix), but different for oblique rotation. Both the matrix P and S are expected for EPM (Educational and Psychological Measurement) manuscripts (B. Thompson & Daniel, 1996). For CFA, the term “loading” is used to refer to either matrix P or S , since in CFA items are set to load on one factor only, and there is only one set of coefficient matrix. When we use the term item loading, we always mean the correlation coefficient for the item on its specific factor.

Figure 3.4 EFA and CFA model

The Number of Factors

As to how many factors should be extracted in the EFA, there are many rules of thumbs. The most used rule is to examine the number of eigenvalue greater than one because it is the default option in most statistics packages like Mplus (Muthe'n & Muthe'n, 2007). However, it is far from perfect because it is hard to defend, especially to decide a factor when eigenvalue is 1.01 and not a factor when eigenvalue is .99. Other approaches, such as bootstrap (Thompson, 1994) and parallel analysis, have more considerable merit but are underused. It is safe to check from different ways leading to the same solution.

Summary

It is clear that reliability and validity estimates are necessary to support the statistical inference based on test scores. However, report on reliability and establishment of validity is not frequently seen in literature. The mostly used strategies for factor analysis for the instrument development in science education are PCA or EFA, even when the instrument has a clear design of subscales and CFA is the most appropriate. CFA has never been reported in the attitude-related instruments published on JCE at present. Chapter Four will report the methods part for all administrations for different versions of ASCI.

Chapter Four

Method

The different versions of ASCI were administered for five times in this study during the semester of spring and summer of 2009. Firstly, original ASCI (V1) was administered. Then three revised versions of ASCI were created and given to four different populations. The responses from all administrations were evaluated in terms of psychometric properties and compared with literature results where appropriate. The evaluations had two main foci: reliability and validity.

This method chapter is organized in four parts. The first is the summary of general research methods that are common to all administrations. The second is the scale reconstruction, i.e., using results from ASCI V1 to create meaningful subscales aligned with the general theory of the attitude concept. The third is the gathering of additional validity evidence for ASCI V2 scores, including the discussion of a nomological network and of predictive validity. The last is analysis specific for calculus course such as Chi-square test.

General Research Methods

Instruments

For the first administration, ASCI V1 (Bauer, 2008) was used. As discussed previously, it has twenty pairs of objectives grouped into five subscales to tap students' attitudinal status towards chemistry in general. For the second administration, the revised ASCI (V2) was used. ASCI V2 (Appendix) is a short form of V1. It has eight pairs of objectives

organized in two subscales. ASCI V3 has the same eight items as those in V2, with the only difference in item order of #2 (simple vs complicated) and #8 (chaotic vs organized). V3.1 is the same as V3, except that the word “Chemistry” is changed to “Calculus” in order to measure students’ attitude towards calculus.

Participants and Data Collection

The participants for the five administrations are summarized in Table 4.1 organized on time and version order. ASCI V1 was given in all lab rooms of General Chemistry I & II labs at a large Southeastern Public Research University (SE) during the 4th week of the Spring 09 semester. ASCI V2 was given to all the General Chemistry I Peer-led (PL) sessions on Mar. 27 (two days after the third term exam and after the course drop date) at SE. ASCI V3 was given to chemistry students during the last week of Spring 09 at a large Middle West Public Research University (MW). ASCI V3.1 was given to students in seven calculus classrooms during the last week at SE. Later in the first week of Summer 09 semester, V2 was given to all the Biochemistry students at SE.

Table 4.1 Summary of administrations for different versions of ASCI

ASCI version	# of item	# of scale	Administration time	participants	Major changes
V1	20	5	Near the end of semester	General Chemistry lab at UNH ^a	Original, or V1 (Bauer, 2008)
V1	20	5	2/2 ~ 2/6, 4 th week, Sp09	General Chemistry lab I, II, at SE ^b	Replication of V1
V2	8	2	3/27, 11 week, Sp09	General Chemistry class at SE	Short from V1
V3	8	2	4/27 ~ 5/1, last week, Sp09	Chemistry class at MW ^c	Change item order from V2
V3.1	8	2	4/20 ~ 4/24, last week, Sp09	Calculus class at SE	Chemistry in V3, calculus in V3.1
V2	8	2	5/18, 1 st week, Summer 09	Biochemistry class at SE	Replication of V2

Note: administrations are organized by time.

^a UNH: University of New Hampshire

^b SE: a large Southeastern Public Research University

^c MW: a large Middle West Public Research University

For each administration, the instrument was given to each intact class as a paper-and-pencil test, most at the beginning of the class. Ten students in one lab section were asked

to take the survey twice, before and after the lab experiment, to calculate test-retest reliability. Students were verbally instructed to answer with their feelings toward chemistry in general, rather than to a specific teacher or course. The 10-choice scantron (marked from A through J or from 0 through 9) was used to collect the data. Students were asked to bubble in the name, UID, and their answer to each item on the scantron. Any response with multiple answers, missing data, missing UID or wrong response beyond the supposed range (each response should range from 1 to 7) was excluded for all the analysis below. The same data cleaning process was applied for all the analysis throughout the study. Pattern of missing data was checked for whether the missing data may bias the findings.

Data Analysis Strategy

To accomplish research goals, data from each administration was analyzed for reliability and validity evidence. Various statistics were performed including descriptive statistics, reliability, effect size of group difference, correlation among different concepts, multiple regression to predict chemistry achievement, and factor analysis (exploratory & confirmatory).

All descriptive statistics were performed in SPSS 17.0 for each item score after the negatively stated items were reversely coded. Good normality of the item score distribution was examined by skewness and kurtosis.

Internal consistencies were calculated by Cronbach's alpha for each subscale. Test-retest reliability was obtained for ASCI V1. Factor score was created by adding scores of all the items associated with the factor. Difference in factor scores of student groups at various course levels was quantified using Cohen's d effect size (Cohen, 1988). The guidelines

($d > .2$, small; $d > .5$, medium, $d > .8$, large) are used to interpret the d effect size based on Cohen's standards (1988). Cohen's d reveals how many standard deviation units apart the two groups are on the factor score.

Factor correlation values were measured in two ways. In the traditional way, factor correlations are based on the factor score as the sum of all grouping items. Due to the existence of measurement error, these correlations can be underestimated. Factor correlations obtained via confirmatory factor analysis are corrected for measurement error. Both values are reported to support discussion of how well students discriminate the different scales.

EFA was performed on the correlation matrix of all the item data in SPSS 17.0 to better understand the internal structure of the results each time. To decide the number of factors to extract, the eigenvalue-greater-than-one rule was carefully used, and comprehensive approaches such as scree plot, parallel analysis, and interpretability were used. Bauer performed FA using principal components analysis (PCA) and Varimax rotation, which will be referred to as strategy **A**. Strategy **A** was occasionally used to make easy comparison with literature results. However, PCA is appropriate for the research interest of prediction, which is not the major concern here. Because the research interest is the measure of latent variable and components which are correlated, principal axis factor analysis methods (EFA) and Promax to allow factors to correlate (strategy **B**). Strategy **B** was applied consistently throughout all the FA report if not stated explicitly.

CFA was performed in Mplus 5.2 to estimate how theoretical model fits the data. It was run on a first-order (4-factor solution for ASCI V1, 2-factor for V2, V3 and V3.1), where the latent factors were set to correlate with each other. Using the variance-covariance

matrix of all the item data as indicated by Cudeck (1989), a maximum-likelihood method was employed. All items were set to load on their assumed factors only. Model is identified by fixing the first item on its factor at 1. In general, models based on a large number of scores are likely to have an inflated Chi-square value for the model fit, so it is a good idea to examine three additional fit statistics: if the Comparative Fit Index (CFI) is greater than .95 (some may use CFI less than .90, (Cheng & Chan, 2003)), and the Root Mean Square Error of Estimation (RMSEA) and the Standard Root Mean Square Residue (SRMR) are both less than .08, the model can be considered a good fit to the data (Hu & Bentler, 1999). This criterion will be used consistently for the estimate of model fit. For the CFA, it is important to falsify the plausible rival hypotheses since untested models may fit the same data even better. For the ASCI V1, we tested many possible model options based on responses of reduced number of items, in order to create conceptual meaningful scales for the revised version. For the ASCI V2, when the two-factor model fit was supported by CFA, we further tested the plausible rival hypotheses of one-factor model for the most parsimonious solution.

Scale Reconstruction Based on ASCI V1

A framework for scale reconstruction was created (Fig. 4.1) and the major steps were implemented to refine ASCI. Step 1 is the obtainment of pilot test information, which was ASCI (V1) from literature; Step 2 is the administration of the instrument; Step 3 is the descriptive analysis of mean, standard deviation, pattern of missing data, reliability, and item-total correlations; Step 4 is EFA for the internal structure and comparison with literature; Step 5 is CFA for alternate model fit and revealing aspects of measurement error; and Step 6 is to propose conceptually meaningful scales when there is a lack of

psychometric evidence for existing scales, and to run CFA on the possible revised versions based on the scores of remaining items and reconstructed models. The proposed revised version is then administered to a different population and the process is repeated. Step 7, which we are currently working on in collaboration with others, is extensive administration to independent populations within a similar context. Step 8 (not shown) would involve evaluation in different contexts.

Figure 4.1 Framework for scale development

The ideal candidates for removal from an instrument are items with poor psychometric quality, including those with highly skewed or unbalanced distributions, low variabilities, low item-total correlations, weak loadings on the hypothetical factor (below .35 from EFA), or heavy loadings on multiple factors. Additionally, CFA can reveal items or

scales with correlated errors, which indicates that only one of the correlated items/scales is needed to capture the information. This scale development strategy has been successfully applied to create new scales emerging from factor analysis of test responses in literature (Germann, 1988).

Validity Estimate for ASCI V2 Score

Nomological Network among Attitude, Aptitude and Chemistry Achievement

Correlational analysis among attitude, ability and achievement was performed in SAS 9.13 to support attitude nomological network. Data were obtained from the same general chemistry population as ASCI V2 data. ASCI V2 score (emotion and cognition components) was used to measure students' chemistry attitude. Student demographic information and their ability scores were collected via the registrar's office. Previous ability was measured by the quantitative portion of the Scholastic Aptitude Test (SATM), which has been used to predict the first year chemistry achievement (Scott E. Lewis & Lewis, 2007). . At the end of the semester, students' scores on the First Term General Chemistry Blended Examination from the Examinations Institute of the ACS Division of Chemical Education (40 items) (www4.uwm.edu/chemexams/contact). Due to confidentiality requirements for using the ACS Exam, no test item can be shown here. The distribution for each variable was examined. Scatterplots of each pair of variables were also examined. Consequently, the relationships among variables were summarized using correlation coefficients. The following values (.10 small, .30 medium, .50 large) (51) were used to interpret the magnitude of coefficients.

The distribution for each variable was examined. Scatterplots of each pair of variables were then visually examined. Consequently, these relationships were summarized using correlations coefficients. The following values (.10 small, .30 medium, .50 large) in social science study (Cohen, 1977) was used to interpret the magnitude of coefficients r .

Predictive Validity for ASCI V2 score

Multiple regression analysis was performed in SAS 9.13 to predict student achievement in general chemistry based on scores from ASCI V2 and SATM. The score on the ACS exam was the dependent variable (the variable we want to predict, or D.V.). Three different regression models were tested using combination of predictor variables (the variables we use to make prediction, or independent variable, I.V.). The possible violation of assumptions to run correlation multiple regression include normality, linearity, outliers and homoscedasticity, which may greatly affect the results when violated (Osborne & Waters, 2002). Normality assumption means all the predictor variables (emotion, cognition and SATM), dependent variable (ACS) and prediction error should be normally distributed. Linearity assumption means that there a linear correlation between the I.V. and the P.V. Homoscedasticity assumption means that the error should distribute equally on the both sides of the regression line at any point of the predicted value. Data were checked for possible violations of assumptions, including assumptions of normality, linearity, and homoscedasticity. Influential outliers were examined by studentized residuals and Cook's D. The prediction equation and semi-partial correlations are reported for the best and most parsimonious model.

Chi-square Analysis for V3.1 Participants

In the study of ASCI V3.1 given to calculus students, 7 sections of calculus class instructors agreed to participate. In order to examine the representative of the student sample in the whole college calculus student population, the frequency of surveyed students on declared major was compared with those all the enrolled students without survey by Chi-square analysis and Fisher exact test (Fisher, 1922). For Chi-square analysis, when the cells in the contingency table have less than 5 counts, the test assumption of large sample size may be violated. Fisher exact test is a better estimate when cells have small sample size. In this study, most students belonged to a few majors such as biomedical sciences and engineering major, while many other majors like social science have zero count. Therefore, Fisher exact test was performed along with the traditional Chi-square analysis.

In the next two chapters, results from the original and revised ASCI will be presented, each started with a brief method description and followed by analysis and discussion.

Chapter Five

Quality Evaluation for Original ASCI (V1)

This chapter presents results from quality evaluation of ASCI V1. ASCI V1 was given to each intact class of General Chemistry I and II labs during the 6th week of the Spring 09 semester (from Feb. 2 through Feb 6) at a large Southeastern Public Research University (SE). The data analysis process described by the ASCI developer was applied to this study here. New versions of ASCI based on ASCI V1 results will be proposed.

Results and Discussion

There were 405 complete and correct responses for General Chemistry I labs and 509 responses for General Chemistry II labs. No pattern was found in those missing data. Descriptive statistics are shown in Table 5.1 for each item organized by each subscale described in Bauer's study with all 14 negatively stated items recoded (2008). According to the literature, the "interest and utility" subscale has five items, which are items 15, 2, 6, 12 and 3. The "anxiety" subscale has five items, which are items 19, 16, 8, 20 and 13. The "intellectual accessibility" subscale has five items (4, 5, 1, 10 and 9). The "emotional satisfaction" subscale has four items (11, 14, 17 and 7). The average item scores ranged from 2.31 to 5.82, and standard deviations ranged from 1.27 to 1.71. No item was found to have skewness or kurtosis greater than 1.2, which suggests good normality of the item score. For the General Chemistry I labs, the mean scores for the five items in "interest and utility" subscale were 4.86, 5.13, 4.54, 4.68 and 4.00, which are all above the middle point, suggesting average students feel chemistry is interesting and useful. The item mean scores for the "Anxiety" subscale were 5.1, 5.82, 3.95, 4.14 and 3.95, which suggests

students think chemistry is anxiety producing. For the “intellectual accessibility” subscale, the item means were 2.80, 3.22, 2.6, 2.31 and 4.02, which indicates they normally think chemistry is not intellectually accessible. For the “emotional satisfaction” subscale, the item means were 3.63, 3.76, 4.03 and 3.26, which means they are not emotionally satisfied.

Table 5.1 Descriptive statistics for ASCI V1, General Chemistry labs I and II

Item in each subscale			Mean Lab I (N=405),	SD	Mean Lab II (N=509)	SD
Interest & utility						
15r ^a	worthwhile	useless	4.86	1.57	4.92	1.48
2	worthless	beneficial	5.13	1.58	5.14	1.48
6r	good	bad	4.54	1.6	4.56	1.53
12r	interesting	dull	4.68	1.6	4.56	1.61
3r	exciting	boring	4.00	1.54	4.05	1.61
Anxiety						
19r	tense	relaxed	5.1	1.36	4.94	1.38
16r	work	play	5.82	1.36	5.65	1.46
8r	scary	fun	3.95	1.41	4.06	1.44
20r	insecure	secure	4.14	1.4	4.16	1.36
13r	disgusting	attractive	3.95	1.3	3.92	1.44
Intellectual accessibility						
4	complicated	simple	2.80	1.52	2.91	1.51
5	confusing	clear	3.22	1.5	3.38	1.51
1r	easy	hard	2.6	1.27	2.98	1.45
10	challenging	unchallenging	2.31	1.35	2.57	1.47
9r	comprehensible	incomprehensible	4.02	1.5	4.26	1.52
Fear						
18	safe	dangerous	3.88	1.39	3.78	1.44
Emotional satisfaction						
11r	pleasant	unpleasant	3.63	1.51	3.69	1.53
14r	comfortable	uncomfortable	3.76	1.39	3.91	1.39
17	chaotic	organized	4.03	1.62	3.97	1.54
7r	satisfying	frustrating	3.26	1.71	3.44	1.71

Note: Each score should range from 1 to 7, and 4 is in the middle point. Items are organized by each subscale in the same order as in the literature. Higher score means students feel chemistry is interesting and useful, anxiety producing, intellectually accessible, dangerous and emotional satisfying. Item 16 has the highest mean, and item 10 has the lowest mean, which indicates they feel chemistry is work rather than play, and is challenging.

r^a: item score is reversed before averaging.

The internal consistencies for each subscale using the listwise deletion are in Table 5.2. Cranbach's alpha was .82, .71, .79 and .74 for the General Chemistry I labs for each subscale, and .85, .79, .82 and .78 for General Chemistry II labs, which are all above satisfactory level .70, and comparable to the literature results. The test-retest (before and after the lab) reliability was above .9 and better than literature report. From these analyses, our instrument data has a very good reliability.

Table 5.2 Internal consistency and test-retest reliability for V1, General Chemistry labs

Scale (Items)	Internal consistency by Cronbach's alpha			Test-retest reliability by Pearson correlation	
	Lab I (N=405)	Lab II (N=509)	Bauer's study	for our sample (N=10)	Bauer's study
Interest&Utility (15,2,6,12,3)	.82	.85	.83	.91	.74
Anxiety (19,16,8,20,13)	.71	.79	.77	.96	.64
Accessibility (4,5,1,10,9)	.79	.82	.78	.96	.71
Emotional satisfaction (11, 14,17, 7)	.74	.78	.79	.96	.72

Item loadings from EFA are listed in Table 5.3 along with the loading Bauer reported. For the two subscales, "Interest and utility" and "Intellectual accessibility", all items are loaded well on the assumed factors in the literature. For the subscales "anxiety" and "emotional satisfaction", some items are loaded on more than two subscales. For example, item 8, which is about "scary" vs "fun", has the item loading of -.38, .26, .53 and -.15 on the four subscales ("interest and utility", "anxiety", "intellectual accessibility" and "emotional satisfaction") for General Chemistry I labs and has the loading of -.49, .33, .40 and -.20 for General Chemistry II labs. It is hard to tell since this item should be loaded on "Interest and utility", however sometimes it can load on "intellectual accessibility". Similar loading patterns for the three data sets indicate that different

student samples from different institutions and different levels may respond to survey items in a similar way.

Table 5.3 The item loadings for V1, General Chemistry labs

Item			General Chemistry I labs				General Chemistry II labs				Literature			
			f1	f2	f3	f4	f1	f2	f3	f4	f1	f2	f3	f4
	Interest and utility		use	anx	accs	emot	use	anx	accs	emot	use	anx	accs	emot
15 ^a	worthwhile	useless	.75	-.22	.01	.06	.85	.05	-.08	.06	.85	.01	-.06	-.11
2	worthless	beneficial	-.68	.21	.05	.04	-.79	-.01	.09	-.06	-.79	-.1	.03	-.04
6 ^a	good	bad	.68	-.20	-.16	.13	.72	-.22	-.12	.17	.71	.05	-.2	-.04
12 ^a	interesting	dull	.80	-.17	-.13	-.01	.77	-.31	.00	.05	.67	.32	.02	-.15
3 ^a	exciting	boring	.69	.08	-.24	-.08	.57	-.48	-.03	.02	.58	.38	-.05	-.09
Anxiety														
19 ^a	tense	relaxed	-.17	.55	.45	.31	-.23	.65	.39	-.11	-.14	-.75	.32	.02
16 ^a	work	play	-.14	.23	.36	.71	-.05	.71	.39	-.03	.06	-.74	.23	-.15
8 ^a	scary	fun	-.38	<u>.26</u>	.53	-.15	-.49	.33	.40	-.20	-.35	-.6	.18	.16
20 ^a	insecure	secure	-.20	.64	.37	-.17	-.35	.46	.16	-.43	-.34	-.53	.23	.29
13 ^a	disgusting	attractive	-.55	<u>.44</u>	.08	.16	-.58	.45	.12	-.12	-.42	-.53	-.01	.11
	Intellectual	Accessibil ity												
4	complicated	simple	-.05	.17	.72	.05	-.06	.22	.76	-.02	-.03	-.13	.8	-.13
5	confusing	clear	-.10	.04	.78	-.06	-.25	.18	.77	-.13	-.24	-.33	.75	.06
1 ^a	easy	hard	.19	-.24	-.70	-.07	.29	-.07	-.71	.18	.13	.18	-.73	-.34
10	challenging	unchallen ging	.08	.09	.69	.36	.20	.25	.74	-.03	.29	-.36	.54	-.01
9 ^a	comprehens ible	incompre hensible	.49	-.12	-.52	.20	.54	-.11	-.51	.32	.38	-.03	-.52	-.41
Fear														
18	safe	dangerous	.09	-.29	-.18	.68	-.01	-.03	.00	.87	.03	.05	-.05	-.85
	Emotional	Satisfactio n												
11 ^a	pleasant	unpleasan t	.60	-.13	-.50	-.10	.55	-.47	-.32	.18	.5	.44	-.35	-.27
14 ^a	comfortable	uncomfort able	<u>.46</u>	-.42	-.48	.03	.52	-.35	-.31	.37	.48	.43	-.35	-.28
17	chaotic	organized	-.25	.73	.08	-.07	-.25	.11	.28	-.55	-.44	-.34	.32	-.15
7 ^a	satisfying	frustrating	<u>.49</u>	-.07	-.67	.03	.56	-.32	-.43	.18	.41	.3	-.46	-.28

Note: EFA is performed in SPSS 17.0. Same parameters were used including principal components methods and Varimax (orthogonal) rotation using the covariance matrix. Four factors are extracted for comparison. Item loadings on the assumed factors are highlighted in bold along with the literature loading. The item loadings with different loading pattern are italic.

^a negatively stated

Factor scores (created by adding scores of all the items associated with the factor) and factor correlation values are listed in Table 5.4.1. General Chemistry II lab students score

slightly higher than General Chemistry I lab students in the “intellectual accessibility” subscale. There is no significant difference in other subscales for these two populations. Compared with the literature, our data are lower in the “intellectual accessibility” subscale and higher in the “fear” subscale. Our chemistry major students score relative higher in the “anxiety” and “emotional satisfaction” than the non-major students. They experienced strong feelings but we don’t know for sure due to the small sample size. Factor correlation pattern is very similar, which indicates the instrument function similarly across different populations.

Table 5.4.1 Factor score and Pearson correlations for V1

	Interest&use	Anxiety	Access	Fear	Emotion	Interest&use	Anxiety	Access	Fear	Emotion
	General Chemistry I lab (n=405)					General Chemistry II lab (n=509)				
Mean ^a	54.9	59.9	33.2	47.9	44.5	54.6	59.1	37.0	46.3	45.9
SD	13.3	15.7	17.6	23.2	19.8	13.7	17.4	19.0	24.0	20.1
	Chemistry major students in lab I (N=12)					Chemistry major students in lab II (N=12)				
Mean	62.6	64.5	42.8	54.1	46.4	61.4	66.7	45.2	50.6	53.6
Factor	correlation									
Interest&Use		-0.55	0.40	-0.18	0.63		-0.63	0.38	-0.15	0.64
Anxiety			-0.64	0.17	-0.75			-0.66	0.19	-0.79
Access				-0.17	0.68				-0.18	0.67
Fear					-0.25					-0.28

Table 5.4.2 Subscale scores and Pearson correlations reported by Bauer (2008)

From literature	Interest & use	anxiety	access	fear	emotion
Mean ^a	56	60	44	38	45
Mean of chemistry major	82	43	46	41	70
Factor	correlation				
Interest & use		-0.51	0.32	-0.15	0.64
anxiety			58	.15	-0.72
access				-0.19	0.62
fear					-0.22

* Subscale scores in percentage for comparison (scale value 1= 0%, 7=100%).

CFA was performed to estimate goodness of the 4-factor solution. The five items, which are items 15, 2, 6, 12 and 3, were set to load on the factor "interest and utility" only. The items 19, 16, 8, 20 and 13, were set to load on factor "anxiety" only; and so on for the factors "intellectual accessibility" and "emotional satisfaction". The estimation of the 4-factor model fit for General Chemistry I lab is (Table 5.5): χ^2 (N = 405, df = 146, p = .00) = 618.5, CFI = **.86**, RMSEA = 0.089, SRMR = .076. For General Chemistry II lab is: χ^2 (N = 509, df = 146, p = .00) = 692.9, CFI = **.89**, RMSEA = 0.086, SRMR = .079. Since CFI was less than .95 and RMSEA was greater than .08, the overall model doesn't fit the data reasonably well.

Table 5.5 Fit statistics of V1 for four-factor CFA

Fit Statistic	Lab I	Lab II
χ^2	618.5	692.9
df	146	146
p	.00	.00
N	405	509
CFI	.86	.89
RMSEA	.089	.086
SRMR	.076	.079

Note: χ^2 = Chi-square, df = degree of freedom, N = sample size, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual

Factor correlation from CFA is shown in Table 5.6. The correlation between the "anxiety" and "emotional satisfaction" constructs is about -.97, which means these two subscales are strongly correlated and redundant.

Table 5.6 Factor correlation for V1 from CFA

	Anxiety	Access	Emotional satisfaction	Anxiety	Access	Emotional satisfaction
	Lab I			Lab II		
Interest & utility	-.72	-.46	.80	-.77	-.49	.84
Anxiety		.83	-.98		.82	-.97
Intellectual Accessibility			-.85			-.82

Proposal for Possible Revisions of ASCI

Because no item exhibited an unexpected distribution or contributed negatively to internal consistency, the descriptive analysis did not indicate any item candidates for removal. This result reflected the relatively high quality of ASCI VI. EFA results revealed the item loading pattern to be similar to the literature report, which yielded a smaller number of factors than intended. CFA results indicated that the proposed factors did not produce an acceptable model fit and contained redundancies, revealing the need to refine the instrument by reconsidering its intended scale structure.

Given the existing items, there are various possible combinations for creating scales for a new version. Our first step was simply to look at the scales individually. Table 5.7 presents the model fit results from CFA for six one-scale versions. For the single scale of “intellectual accessibility”, CFA was performed with all its items (1, 4, 5, 9, and 10) loaded on one factor, with poor fit statistics (Option 1-A). Because Item 9 loaded on multiple factors from the EFA of the whole instrument (Table 5.3), we excluded it and ran CFA again based on the remaining four items. Both fit statistics are improved: CFI = .99 and SRMR = .02, which supports the one-factor structure (Option 1-B).

Table 5.7 CFA results for Scale Reconstruction based on ASCI (V1) subscales

Option	# Of Scale	Items	Model Fit Statistics			Comments
			CFI	RMSEA	SRMR	
1-A	1	1, 4, 5, 9, 10	0.94	0.15	0.08	9 harms the validity of intellectual accessibility scale; removing it produces a good fit
1-B	1	1, 4, 5, 10	0.99	0.08	0.02	
2-A	1	2, 3, 6, 12, 15	0.95	0.14	0.04	removing 15 (redundant with 2) produces a better fit; regardless, the scale is conceptually problematic
2-B	1	2, 3, 6, 12	0.99	0.09	0.02	
3	1	8, 13, 16, 19, 20	0.97	0.09	0.04	good fit for the anxiety scale
4	1	7, 11, 14, 17	0.99	0.07	0.02	good fit for this emotional satisfaction set, also a good match with attitude theory
V2	2	1, 4, 5, 10, 7, 11, 14, 17	0.96	0.08	0.04	final version captures both intellectual accessibility and emotional satisfaction, congruent with two-component attitude theory

For the scale of “interest and utility”, when all items (2, 3, 6, 12, 15) are set to load on one factor for CFA (Option 2-A), the fit statistics are: χ^2 (N = 509, df = 10, p = .00) = 54.2, CFI = .95, RMSEA = .14. Based on model modification indices, the χ^2 value would decrease by 42.5 if the correlation between error terms of Items 2 and 15 was added to the model. One of these two items was therefore a good candidate for deletion. A CFA model was run without Item 15 (Option 2-B). The fit statistics are: χ^2 (N = 509, df = 6, p = .00) = 9.7, CFI = .99, SRMR = .02, which supports the one-factor model. However, since the scale actually has two concepts (interest and utility), and it is not desirable for one subscale to have more than one concept, it was not included in the revised version. The CFA model fits are acceptable for the subscales of “anxiety producing” and “emotional satisfaction” with all the grouping items (Options 3 and 4). Since “anxiety producing” and “emotional satisfaction” scores are linearly related and redundant, only one scale was chosen for the revised version for administration. “Emotional satisfaction” fits better with the affect component of the attitude framework.

In order to capture both scales, cognition and affect, we propose the ASCI V2. It consists of four items from “intellectual accessibility” about the difficulty of chemistry, and four

items from “emotional satisfaction” about how good students feel about chemistry. The model fit of two-factor structures based on the eight item scores was tenable (Table 5.7). The next step is to determine whether students discriminate these two factors in an instrument that contains only the relevant eight items, which requires the administration of ASCI V2 to another student sample.

Summary

Based on above analysis, ASCI V1 functions similarly across our population and those described by Bauer. It did not provide meaningful interpretation for all these 20 items, and did not reflect the underpinning theoretical framework, because the way to group the items is not stable and inconsistent with factor analysis results. The analysis of this administration leads to the modification of a new version. ASCI V2 was proposed and hopefully can be more conceptually meaningful. It has eight items across two subscales. One is intellectual accessibility and the other is emotional satisfaction, therefore, it was congruent with the cognitive and affective components of attitude theory. ASCI V2 and two more derivative versions (V3 and V3.1) were further given to different student populations and will be discussed in the next chapter.

Chapter Six

Quality Evaluation for Revised ASCI

This chapter describes quality evaluation results from four administrations of the modified ASCI. All of these modified versions (V2, V3, V3.1) have eight items grouped across two subscales. The following presentation of results is organized based on each administration in the same order as in Table 4.1.

ASCI V2 was given to the General Chemistry I Peer-Led (PL) classes on March 27 at the beginning of the class at a large Southeastern Public Research University, two days after the third term exam and after the drop date. ASCI V3 and V3.1 were created on the basis of V2 to examine if changed item order could lead to better validity evidence. V3.1 was modified from V3 to assess the effectiveness in a calculus context to measure students' attitude toward calculus. At last, ASCI V2 was given to another student group enrolled in Biochemistry course.

Quality Evaluation for Revised ASCI V2, Peer-Led classes

Results and Discussion

From 375 set of data returned, 354 respondents with the complete set were used for data analysis. Descriptive statistics were performed for each item score after all four negatively stated items were recoded. Average scores for each item from the 354 respondents ranged from 2.50 to 4.26, and standard deviation ranged from 1.28 to 1.70 (Table 6.1). No item was found to have skewness or kurtosis greater than .7, which suggests good normality of the scores. The item scores on V2 are comparable to the same

item scores in V1. The mean scores for General Chemistry I lab students are comparable to the scores constructed for a similar sample of students who took ASCI V1 in the General Chemistry I Laboratory (Table 6.1).

Table 6.1 Descriptive statistics for ASCI V2, PL classes

Item #				Lab I, n=405, V1		PL, n=354, V2	
V1	V2			Mean	SD	Mean	SD
1	1r	easy	hard	2.60	1.27	2.81	1.28
4	2	complicated	simple	2.80	1.52	2.95	1.43
5	3	confusing	clear	3.22	1.50	3.36	1.40
14	4r	comfortable	uncomfortable	3.76	1.39	3.64	1.36
7	5r	satisfying	frustrating	3.26	1.71	3.24	1.70
10	6	challenging	unchallenging	2.31	1.35	2.50	1.50
11	7r	pleasant	unpleasant	3.63	1.51	3.38	1.41
17	8	chaotic	organized	4.03	1.62	4.26	1.66

Note: Item score is reversed before averaging.

Each item score should range from 1 to 7, while 4 is in the middle point. Higher score means students feel chemistry is intellectually accessible, emotional satisfying. Item 8 has the highest mean of 4.26, and item 6 has the lowest mean of 2.50, which indicates they feel chemistry is organized, and is challenging.

Internal consistency reliability was measured by Cronbach's alpha for each subscale.

Cronbach's alpha was .82 and .79 for the "intellectual accessibility" and "emotional satisfaction" subscales, respectively. Both values are above the rule-of-thumb satisfactory level of .7, and comparable to ASCI (V1) and the literature results.

Factor scores were created by summing the items within each subscale: 2.91 (31.8% if converted to a percentage) for intellectual accessibility and 3.63 (43.8%) for emotional satisfaction, with a correlation of .64 between the two factors. Factor scores and correlation for this administration of ACSI V2 were very similar to those calculated from ASCI V1 data for a similar sample of students, which indicate these eight items function similarly even when the other 12 items are removed from the instrument.

Table 6.2 Subscale scores and Pearson correlations for ASCI V2, PL classes, along with results from General Chemistry I labs

	PL (n=354), V2		Gen. Chemistry I lab (n=405), ASCI V1				
	Access	Emotion	Interest&Use	Anxiety	Access	Fear	Emotion
Mean	2.91 (31.8 ^a)	3.62 (43.8 ^a)	54.9	59.9	33.2	47.9	44.5
SD	1.13	1.20	13.3	15.7	17.6	23.2	19.8
Factor	correlation						
Interest & Use				-0.55	0.40	-0.18	0.63
Anxiety					-0.64	0.17	-0.75
Access		.64				-0.17	0.68
Fear							-0.25

^a Subscale scores in percentage for comparison (scale value 1= 0%, 7=100%).

Table 6.3 Internal consistency for PL classes, along with General Chemistry I Lab I and Bauer's results

	Internal consistency by		Cronbach's alpha
	PL(N=354), V2	lab I (N=405), V1	Bauer's result (2008), V1
Intellectual Accessibility ^a	.82	.79	.78
Emotional satisfaction	.79	.74	.79

^a The ASCI V1, Intellectual accessibility has five items (4,5,1,10, 9), V2 has its four without item 9.

An exploratory factor analysis for V2 was performed using strategy **A** including principal components methods and Varimax rotation as in the literature. Two factors were extracted. Item loadings are listed in Table 6.4. All items were loaded well (all loadings were greater than .6 here) on the assumed factors in the literature. The loading pattern for the short version was exactly what we expected for the revised version.

Table 6.4 The item loadings for V2, PL classes

Item # in each scale	V2		loading	
			F1	F2
Intellectual	Accessibility			
1r ^a	easy	hard	0.41	0.66
2	complicated	simple	0.34	0.75
3	confusing	clear	0.45	0.68
6	challenging	unchallenging	0.00	0.86
Emotional	Satisfaction			
4r	comfortable	uncomfortable	0.74	0.29
5r	satisfying	frustrating	0.72	0.36
7r	pleasant	unpleasant	0.75	0.38
8	chaotic	organized	0.71	0.02

Note: EFA is performed in SPSS 17.0. Strategy A was used including principal components methods and Varimax (orthogonal) rotation using the covariance matrix. 2 factors are extracted for comparison. Item loadings on the assumed factors are highlighted in bold.

r^a: negatively stated

CFA was performed to estimate goodness of fit for the 2-factor model. Items 1, 2, 3 and 6 were set to load on factor “intellectual accessibility” only; items 4, 5, 7 and 8 were set to load on factor “emotional satisfaction” only, and the two factors were allowed to correlate. In order to investigate a more parsimonious model, the alternate 1-factor model solution was also sought. Models were identified by fixing the first item on its factor at 1. Fig. 6.1 presents the standardized parameter estimates for both models.

Parameter estimate for one-factor model

Parameter estimate for two-factor model

Figure 6.1 Standardized parameter estimate for one-factor and two-factor model (N=354). The large ovals designate the latent variables, the small circles are the residual variances, and the rectangles indicate the observed variables. Items were set to load on their assigned factors only. All item loadings are significantly different from 0 ($p < .01$).

The estimation of the 2-factor model fit (Table 6.5) test was: χ^2 (N = 354, df = 19, $p = .00$) = 77.0, CFI = .95, RMSEA = 0.093, SRMR = .042. Since CFI was .95, and RMSEA was close to .08, SRMR was less than .08, the overall model fits the data reasonably well. The estimation of the 1-factor model fit was: χ^2 (N = 354, df = 19, $p = .00$) = 156.1, CFI = .89, RMSEA = 0.14, SRMR = .056. Since CFI was less than .95, and RMSEA was greater than .08, the overall 1-factor model does not fit the data. Therefore, the 2-factor model is more tenable.

Table 6.5 Fit statistics of V2 results for 1- and 2-factor CFA

Fit Statistic	Value	
Model	one-factor	two-factor
χ^2	156.1	77.0
df	19	19
p	.00	.00
N	354	354
CFI	.89	.95
RMSEA	.14	.093
SRMR	.056	.042

Note: χ^2 = Chi-square, df = degree of freedom, N = sample size, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual

The two aspects of attitude measured by ASCI V2 are expected to be related, though not redundant, which is supported by the 2-factor CFA: the correlation between the "intellectual accessibility" and "emotional satisfaction" constructs is .80.

From the above results, the results of V2 exhibit better psychometric quality to measure and discriminate meaningful component for attitude construct.

Nomological Network among Attitude, Aptitude and Chemistry Achievement

Previous aptitude score such as SATM is often used for college admission in the United States due to its predictive power of their performance in college science courses (Scott E. Lewis & Lewis, 2007). In this study ACS score was used as part of the final exam for the General Chemistry I course and expected to correlate with SATM and ACTM. In previous studies, low to moderate attitude-achievement correlation was found. Here ASCI score is expected to correlate with ACS. Since cognition part (intellectual accessibility) is asking students' opinion about the difficulty of the chemistry, cognition score may be correlated with SATM.

Results and Discussion

There were 456 students enrolled in the discussion sections of the General Chemistry I course and had ACS score, 383 had SATM scores, 292 had ACTM scores, and 354 had ASCI V2 score. The entire population was included in the correlation analysis.

First, we examined the distribution for each variable. The mean, standard deviation, skewness and kurtosis values are presented in Table 6.6. All the skewness and kurtosis values are less than .32, which indicates normal distribution. Scatterplots of each pair of variables were then examined. No bivariate outliers or nonlinear relationships were found. Attitude scores for SAT and ACT test takers were not significantly different.

Table 6.6 Descriptive analysis for attitude, aptitude score and final score on ACS

Variable	N	Mean	Std Dev	Skewness	Kurtosis
access	354	2.91	1.13	0.32	-0.25
emotion	354	3.63	1.2	-0.03	-0.08
SATM	383	548.5	67.1	0.19	0.23
ACTM	292	23.19	3.66	0.19	-0.22
ACS	456	23.17	6.2	0.02	-0.07

The relationships among these variables were summarized with correlation coefficient, as presented in Table 6.7, which in essence allows examination of a small nomological network. All relationships were positive as anticipated, significant at the .05 level. The correlation between ACS and other four variables is classified as moderate, based on the guideline for interpreting the magnitude of coefficient r (.10 small, .30 moderate, .50

large) in social science study (Cohen, 1977). The attitude-achievement correlation (coefficients: .30 and .34) is consistent with extensive studies (Germann, 1988; Reynolds & Walberg, 1992; Salta & Tzougraki, 2004) and not as strong as the ability-achievement correlation (.45 and .46). Since attitude towards chemistry and mathematical ability are conceptually distinct, it is reassuring that low correlations between constructs related to those different concepts are observed (coefficients: .19, .14, .13 and .15). Since two components of the attitude concept, cognition and emotion, should be related but not identical, the high correlation between these two variables from ASCI V2 (coefficient: .64) is also reassuring. Finally, as expected, SATM and ACTM, both intended to measure the mathematics ability, reveal the highest correlation of all (coefficient: .74).

Table 6.7 Pearson correlation among attitude, aptitude and achievement, N = 456, Prob > |r| under H₀: Rho=0

	Emotion	SATM	ACTM	ACS
Cognition (Intellectual accessibility part of ASCI)	.64	.19	.14	.30
Affect (Emotional satisfaction part of ASCI)		.13	.15	.34
SATM			.74	.45
ACTM				.46

*P < 0.05 for all the correlation, correlation coefficients with ACS (dependent variable) are in bold.

In sum, all five variables correlate with each other as expected, and thus provide evidence for a small but reasonable nomological network.

Predictive Validity to Predict Chemistry Achievement

Multiple regression analysis was performed to predict the students' achievement in general chemistry measured by ACS from three predictor variables: ASCI V2 cognition, emotion and SATM. For the 456 students in the above correlation analysis, 297 of them

have complete data for SATM, ASCI V2 and ACS score. All 297 students were used in the following regression analysis. We expect that the attitude can account for the different portion from SATM in the variance of chemistry achievement.

Results and Discussion

All three predictors were entered into an initial regression model: emotional satisfaction (ASCI V2), intellectual accessibility (ASCI V2), and mathematics ability (SATM). The maximum values of studentized residuals and Cook's D were 3.3 and .048, respectively. These small values led us to believe that none of the cases were exerting undue influence on the regression analysis. An examination of a scatterplot of the residuals with the predicted values revealed no violations of the linearity or homoscedasticity assumptions, and the distribution of the residuals was found to be approximately normal (skewness = .098, kurtosis = -.025). Based on the screening of the data it appeared appropriate to proceed with the result analysis.

The obtained R^2 value was .286, suggesting about 28.6% of the variance in ACS Exam score was accounted for by the three predictors. From squared semipartial correlation of the predictors, SATM uniquely accounted for 17.7% of the variability in ACS score, emotional satisfaction uniquely 2.4% and intellectual accessibility .3%. The regression coefficient for the intellectual accessibility was found to not be significantly different from zero. Although intellectual accessibility and SATM both correlate moderately with ACS score, SATM partially overlaps with the intellectual accessibility. This is a reasonable result, since intellectual accessibility of chemistry as perceived by General Chemistry I and II students is expected to be highly influenced by mathematical ability.

Therefore, a more parsimonious second model was run with only emotional satisfaction and SATM as predictors.

For the two-predictor model, the obtained R^2 value was .283, suggesting about 28.3% of the variance in ACS Exam score was accounted for by the two predictors. The adjusted R^2 was .278. It appears that the model accounted for an acceptable proportion of the variability in ACS Exam scores. Cohen's effect size $f^2 = R^2 / (1 - R^2)$ was computed to be .40, which can be interpreted as a large effect. The root mean square error was 4.95, which indicated that predictions of ACS Exam scores from this model tend to be off by about 5 points and cannot be regarded as exact predictions.

The obtained prediction equation was:

$$\text{Predicted ACS score} = -2.29 + 1.24 * \text{Emotion} + 0.038 * \text{SATM} \text{ (Equation 6.1)}$$

The regression coefficients were statistically significant. Since the magnitudes for each variable are different, the regression coefficients should be standardized for better comparison of their contributions to ACS Exam score prediction. Values of .25 and .44 were obtained for emotion and SATM, respectively. The intercept with mean-centered predictors was 23.5, so the predicted ACS score for a student with an average emotional satisfaction score and average SATM score is 23.5. SATM scores uniquely account for 18.8% of the variability in ACS Exam scores, while emotional satisfaction uniquely accounted for 6.16%.

A two-predictor model using intellectual accessibility and SATM was also examined. SATM uniquely accounted for 18.0% of the variability in ACS score, while intellectual accessibility uniquely accounted for 4.05%. The obtained R^2 value was .262, suggesting

about 26% of the variance in ACS test was accounted by the two predictors, which is lower than the two-predictor model with emotional satisfaction and SATM.

Comparisons of the three regression models suggest that a two-predictor model based on emotional satisfaction and SATM represents the best model to predict ACS Exam score for this data. In terms of predictive validity, the emotional satisfaction score from ASCI V2 can be used to improve predictions of chemistry achievement that would result from the use of a predictor of mathematical ability alone, which supports the idea that emotional satisfaction is a distinct measured construct.

Evaluation of ASCI V3 for Chemistry Class at University MW

In ASCI V2, items 1, 2 and 3 were all about the intellectual accessibility. I am interested to see how the survey works when the items from two scales are more mixed. For this purpose, the item order of items 2 and 8 was swapped, and thus the new version V3 was created. Hopefully it might reduce possible measurement error and achieve better quality for V3. ASCI V3 was given to chemistry students at a large Middle West Public Research University (MW) during the week of April 27, 2009. There were 309 responses returned, 305 of which with complete sets of data were used for the following analysis. The results of ASCI V1 from PL classes are also listed for comparison.

Results and Discussion

Descriptive statistics were performed for each item score after all four negatively stated items were recoded (Table 6.8). The average scores for each item ranged from 3.07 to 4.44, and standard deviation ranged from 1.29 to 1.58. No item was found to have skewness or kurtosis greater than .93, which suggests good normality of the scores. Each

item mean score was higher than that in the V2 version for PL students, which suggests a more positive attitude for the MW students.

Table 6.8 Descriptive statistics for ASCI V3, MW chemistry

Item #			MW, n=305, V3	PL, n=354, V2
			Mean	SD
1r	easy	hard	3.64	1.48
2 (in PL, #8)	chaotic	organized	4.44	1.29
3	confusing	clear	4.26	1.40
4r	comfortable	uncomfortable	4.41	1.35
5r	satisfying	frustrating	4.29	1.58
6	challenging	unchallenging	3.07	1.29
7r	pleasant	unpleasant	4.13	1.35
8 (in PL, #2)	complicated	simple	3.46	1.33

Note: Item score is reversed before averaging.

Each score should range from 1 to 7, and 4 is in the middle point. Higher score means students feel chemistry is intellectually accessible, emotional satisfying. Item 2 has the highest mean of 4.44, and item 6 has the lowest mean of 3.07, which indicates they feel chemistry is organized, and is challenging.

Internal consistencies were calculated for each subscale using the listwise deletion (Table 6.9). According to instrument design, the “intellectual accessibility” subscale has four items, which are items 1, 8, 3 and 6. The “emotional satisfaction” subscale has four items, which are items 4, 5, 7 and 2. Cronbach’s alpha was .77 and .78 for the 2 subscales, which are all above satisfactory level .70, and comparable to the Bauer’s results.

Table 6.9 Internal consistency for V3, MW chemistry

Internal consistency by Cronbach’s alpha			
	MW (N=305), V3	PL (N=354), V2	Literature (Bauer, 2008) V1
Intellectual accessibility	.77	.82	.78 ^a
Emotional satisfaction	.78	.79	.79

^a The ASCI V1, intellectual accessibility scale has five items.

An exploratory factor analysis was performed using strategy **B** (principal axis factor analysis methods and Promax). Two factors are extracted. Item loadings are listed in Table 6.10. All items were loaded well on the assumed factors except items 1 and 3.

Table 6.10 The item loadings for V3 at MW and V2 from PL sessions at SE

Item # in each scale			Loading MW, V3		Loading PL, V2	
			F1	F2	F1	F2
Intellectual accessibility			N=305		n=354	
1r ^a	easy	hard	0.35	0.49	0.38	0.38
8 (in V2, #2)	complicated	simple	0.02	0.76	0.01	0.81
3	confusing	clear	<i>0.45</i>	<i>0.37</i>	0.19	0.66
6	challenging	unchallenging	-0.19	0.81	-0.11	0.73
Emotional satisfaction						
4r	comfortable	uncomfortable	0.74	0.00	0.80	-0.06
5r	satisfying	frustrating	0.89	-0.13	0.79	-0.01
7r	pleasant	unpleasant	0.76	-0.08	0.80	0.03
2 (in V2, #8)	chaotic	organized	0.39	0.08	0.42	0.06

Note: EFA is performed in SPSS 17.0. Strategy **B** was used including principal axis factor analysis methods and Promax rotation using the covariance matrix. 2 factors are extracted for comparison. Item loadings on the assumed factors are highlighted in bold. Items not loaded on the assumed factors in the literature are in italic.

^a: negatively stated

Factor scores created by summing item scores and factor correlation value are listed in Table 6.11. Factor score is 3.61 for intellectual accessibility and 4.31 for emotional satisfaction, with a correlation of .51 between them. Factor correlation was similar with that from V2 of for peer-led classes, which indicated the factor function similarly across different versions. Factor score for MW students is higher in both scales, which indicates they feel chemistry is more intellectually accessible and satisfying.

Table 6.11 Factor scores and Pearson correlations for V3, MW and PL classes at SE

	MW, V3 (n=305)		PL, V2 (n=354)	
	Intellectual access	Emotion	Intellectual access	Emotion
Mean	3.61	4.31	2.91	3.63
SD	1.07	1.08	1.13	1.20
Factor correlation				
Intellectual accessibility		0.51		0.64

Confirmatory factor analysis (CFA) was performed to estimate the influence of the measure error and the fit of 2-factor model. The estimation of the 2-factor model fit for the MW chemistry class is (Table 6.12): χ^2 (N = 305, df = 19, p = .00) = 113.2, CFI = .89, RMSEA = 0.13, SRMR = .07. Since CFI was less to .95, and RMSEA was greater than .08, the overall model does not fit the data well. The source of misfit is the relatedness for the error term of items 6 and 8. The χ^2 would decrease 45.0 if this association is added to the model.

Table 6.12 Fit statistics of V3 at MW from two-factor CFA

Fit Statistic	Value
χ^2	113.2
df	19
p	.00
N	305
CFI	.89
RMSEA	.13
SRMR	.07

Note: χ^2 = Chi-square, df = degree of freedom, N = sample size, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual

Factor correlation from CFA between the "intellectual accessibility" and "emotional satisfaction" constructs is .66, which is consistent with previous findings.

From the above analysis, the construct validity of ASCI V3 results is not supported by two-factor CFA.

Evaluation of ASCI V3.1 for Attitudes toward Calculus

All versions of ASCI discussed so far are for chemistry attitude. In order to examine how the survey works for the calculus course, the word “chemistry” was changed to “Calculus” to make the Version 3.1. At the similar time of ASCI V3 administration, ASCI V3.1 was given to 7 sections of the calculus course during the first 15 minutes of class (3 from Engineering Calculus II, 1 from Engineering Calculus I, 1 from Engineering Calculus III, 1 from life science Calculus II, and 1 from Calculus I) during the week of April 20th through April 24th. There were 190 responses returned, 187 with complete sets of data and correct UID without multiple answers, which were used for the following analysis.

Results and Discussion

Descriptive statistics were performed for each item score after all four negatively stated items were recoded (Table 6.13). It shows the average scores for each item range from 2.66 to 4.68, and standard deviations range from 1.41 to 1.76. No item was found to have skewness or kurtosis greater than 1, which suggests good normality of the scores.

Table 6.13 Descriptive statistics of ASCI V3.1 for calculus attitude

Item #	Calculus, V3.1	(N=187)	Mean	SD
1r	easy	hard	3.29	1.59
2	chaotic	organized	4.68	1.47
3	confusing	clear	4.09	1.65
4r	comfortable	uncomfortable	4.07	1.55
5r	satisfying	frustrating	3.86	1.76
6	challenging	unchallenging	2.66	1.45
7r	pleasant	unpleasant	3.94	1.49
8	complicated	simple	3.16	1.41

Note: item score is reversed before averaging.

Each score should range from 1 to 7, and 4 is in the middle point. Higher score means students feel calculus is intellectually accessible, emotional satisfying. Item 2 has the highest mean of 4.68, and item 6 has the lowest mean of 2.66 (*italic*), which indicates they feel calculus is organized, and is challenging.

The internal consistencies were calculated for each subscale using the listwise deletion

(Table 6.14). The “intellectual accessibility” subscale has four items, which are items 1, 3,

6 and 8. The “emotional satisfaction” subscale has four items, which are items 2, 4, 5 and

7. Cronbach’s alpha was .83 and .78 for the 2 subscales, which is above satisfactory

level .70, and comparable to the literature results.

Table 6.14 Internal consistency by Cronbach’s alpha for V3.1 calculus sections

Cronbach’s alpha	Calculus V3.1 (N=187)	Literature V1 (Bauer, 2008)
Intellectual accessibility (1,8,3,6)	.83	.78 ^a
Emotional satisfaction (4,5,7,2)	.78	.79

^a The original version for the literature, Intellectual accessibility has five items.

An exploratory factor analysis was performed using strategy **B** (principal axis factor

analysis methods and Promax). Two factors were extracted. Item loadings are listed in

Table 6.15. All items were loaded well on the assumed factors except items 5 and 2. It is

not clear why items 5 and 2 loaded on the “Intellectual accessibility” scale, instead of the

“satisfaction” scale. Further analysis and cognitive interview need to be done to examine the possible reason for this different data pattern.

Table 6.15 The item loadings for V3.1 Calculus sections from EFA

Item # in each scale			Loading F1	Calculus, 3.1 F2	Loading F1	MW, V3 F2
Intellectual accessibility			N=187		N=305	
1r ^a	easy	hard	0.53	0.29	0.35	0.49
8	complicated	simple	0.65	-0.07	0.02	0.76
3	confusing	clear	0.61	0.20	0.45	0.37
6	challenging	unchallenging	0.81	-0.02	-0.19	0.81
Emotional satisfaction						
4r	comfortable	uncomfortable	0.89	-0.16	0.74	0.00
5r	satisfying	frustrating	-0.15	0.69	0.89	-0.13
7r	pleasant	unpleasant	0.79	-0.02	0.76	-0.08
2	chaotic	organized	0.07	0.88	0.39	0.08

Note: EFA is performed in SPSS 17.0. Strategy **B** was used including principal axis factor analysis methods and Promax rotation using the covariance matrix. 2 factors are extracted for comparison. Item loadings on the assumed factors are highlighted in bold. Items not loaded on the assumed factors in the literature are *italic*.

r^a: negatively stated

Factor scores created by summing associated item score are listed in the Table 6.16 for each course level. Life Sciences Calculus II had the lowest factor score of 3.13 for Intellectual accessibility and 3.36 for emotional satisfaction. For the Engineering Calculus course, the higher level course had significantly higher level of positive attitudes towards calculus, (e.g., intellectually Accessibility score was 3.56, 3.79 and 4.33 for level I, II and III respectively) with the median effect size ranging from .2 to .6, which indicates level III students feel that calculus is more intellectually accessible and emotional satisfying. Calculus I had the similar mean scores with the Engineering Calculus I.

Table 6.16 Factor score for V3.1, calculus sections

Level		Intellectual	Accessibility	Emotion	Satisfaction
	N	Mean	SD	Mean	SD
Life Sciences Calculus II	31	3.17	1.05	3.36	1.27
Calculus I	29	3.53	1.00	3.58	1.01
Engineering Calculus I	16	3.56	1.03	3.56	1.36
Engineering Calculus II	92	3.79	1.08	3.84	1.26
Engineering Calculus III	19	4.33	1.30	4.45	1.27
Overall	187	3.68	1.12	3.76	1.26

Although the trend of attitude difference among these levels was observed from Table 6.17, it is worthwhile to avoid any hasty conclusion, because the student sample here may not represent the whole calculus population, and a lot of factors may exist and affect attitudes. One factor is that, students from different majors may have different attitudes towards chemistry. Non-science major students may hold more negative attitude towards science (Gogolin & Swartz, 1992). The question arises; did the student sample here represent the students population enrolled in calculus in terms of declared major? It means, if the sample has overrepresented percentage of some specific major, the conclusion could be biased. To get a gross impression of the entire enrollment of the class, the frequency of students' declared major for each calculus course level is listed in Table 6.17. Calculus I has the most diverse students from 40 different majors. Life Calculus II consists of students mostly from Biomedical Sciences, Environmental Science & Policy and other majors. All the three levels of the Engineering Calculus I have the students dominantly from engineering or pre-engineering, with the percentage greater than 76%. The frequency of those in this study on declared major was compared with all the enrolled students without the survey by Chi-square analysis and Fisher exact test. For Life Calculus, χ^2 (N = 40, df = 12, p = .15) = 17.1, Fisher value: .21; For the Calculus I,

χ^2 (N = 200, df = 39, p = .91) = 27.8, no Fisher value; For the Engineering Calculus I, χ^2 (N = 279, df = 24, p = .97) = 12.6, Fisher value: .64; Engineering Calculus III, χ^2 (N = 218, df = 20, p = .45) = 20.2, Fisher value: .42. All above Chi-Square tests and fisher values were not significant at the .05 level, which means no evidence to conclude that the student sample in our study and those without survey are different in declared majors.

Table 6.17 The frequency of most declared majors for students at each course level

Course level	Major code	Major of students enrolled	Number	Percent (%)
Calculus I	BMS	Biomedical Sciences	31	15.5
	PGU	Pre-Engineering	27	13.5
	PBI	Pre-Biology/Microbiology	23	11.5
	ESP	Environmental Science & Policy	19	9.5
	CHM	Chemistry	17	8.5
	EGU	Engineering-General	14	7
	Total		200	100
Life Calculus II	BMS	Biomedical Sciences	13	32.5
	ESP	Environmental Science & Policy	13	32.5
	EGU	Engineering-General	2	5
	Total		40	100
Engineering Calculus I	PGU	Pre-Engineering	121	43.37
	EGU	Engineering-General	92	32.97
	PAR	Pre-Architecture	28	10.04
	BMS	Biomedical Sciences	5	1.79
	PBA	COB Pre-Business Admin	5	1.79
	Total		279	100
Engineering Calculus II	EGU	Engineering-General	141	51.65
	PGU	Pre-Engineering	95	34.8
	CHM	Chemistry	9	3.3
	PAR	Pre-Architecture	3	1.1
	Total		273	100
Engineering Calculus III	EGU	Engineering-General	109	50
	PGU	Pre-Engineering	69	31.65
	BCS	Computer Science	10	4.59
	MTH	Mathematics	7	3.21
	CHM	Chemistry	2	0.92
	Total		218	100

For the Engineering Calculus II, χ^2 ($N = 273$, $df = 20$, $p = .09$) = 8.7, Fisher value: .03. Fisher exact test indicated the significant difference at $p < .05$. When examining the roster, 51.7% students declared major of Pre-Engineering and 34.8% declared Engineering-general. For the survey students, 61.5% declared Pre-Engineering (this is larger than those without survey), 24.2% declared Engineering-general. According to the admission requirement (USF, 2008), students meeting or exceeding certain criteria (high school GPA, SAT etc) are granted direct entry to the College, and Pre-Engineering students are “fully admitted to the College after satisfactorily completing Calculus I and II and Physics I and II with labs”. The Calculus attitudes score for Engineering Calculus II could be biased using this sample.

CFA was performed to estimate goodness of fit of the 2-factor model. The estimation of the 2-factor model fit for the Calculus class was (Table 6.18): χ^2 ($N = 187$, $df = 19$, $p = .00$) = 76.2, CFI = .91, RMSEA = 0.13, SRMR = .07. Since CFI was less than .95, and RMSEA was greater than .08, the overall model did not fit the data reasonably well. In terms of possible reason for the misfit, the combination of different level courses for different population (environment, life and general calculus I, II, and III) could be a problem. However, factor analysis for the 92 Engineering Calculus II students didn't improve the model fit. Another reason could be that calculus students didn't use the same subjective words to describe their cognitive and affective attitude towards calculus, since words in ASCI were originally constructed specifically for chemistry students. Cognitive interview may reveal possible hints for calculus attitude items but not performed in this study.

Table 6.18 Fit statistics of V3.1 calculus results from two-factor CFA, along with MW

Fit Statistic	Calculus, V3.1	MW, V3
χ^2	76.2	113.2
df	19	19
p	.00	.00
N	187	305
CFI	.91	.89
RMSEA	.13	.13
SRMR	.07	.07

Note: χ^2 = Chi-square, df = degree of freedom, N = sample size, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual

Factor correlation from CFA between the "intellectual accessibility" and "emotional satisfaction" was .86, which suggests the strong correlation for the two components and consistent with previous findings.

Although the above comparison was made for different courses and different populations, similar pattern appeared consistently. For both cases the survey V3 and V3.1 may not be useful to identify the attitude component for college students. The reliability for each scale is acceptable. The construct validity is not completely confirmed. Some items are not loaded on the assumed factor, and measurement error of items 6 and 8 were correlated, which indicated the decrease of χ^2 about 34.3 for calculus and 50.5 for MW data by adding this correlation into the model. We can't figure out exactly why the different item order can lead to this different response patterns. One possible theory for the item order effect is that ASCI V2 may trigger students to discriminate the trivial difference among the items. Are the first two items, easy vs hard and complicated vs simple, same or different? Maybe students got the cues to find distinctions for each item, and may pay more attention.

In sum, ASCI V3.1 is not yet done for the calculus course at this point.

Evaluation of ASCI V2 for Biochemistry Class

The results of ASCI V3 for MW chemistry students and the V3.1 for the calculus students didn't exhibit simple and clean internal structure. After examining the source of misfit, the error term of items 6 and 8 was found to covary and harmed the model fit for both situations. Meanwhile, the cleaner 2-factor solution was confirmed by ASCI V2 results. The investigator decided to move back to V2. Hopefully ASCI V2 can reproduce the good model fit result.

ASCI V2 was given to the students enrolled in Biochemistry course at the last 15 minutes of the class on May 18. There were 105 responses returned, 88 with complete data, which were used for the following analysis.

Results and Discussion

Descriptive statistics were performed for each item score after all 4 negatively stated items were recoded (Table 6.19). The average scores for each item ranged from 2.84 to 4.55, and standard deviation ranged from 1.25 to 1.62. No item was found to have skewness or kurtosis greater than **.9**, which suggests good normality of the item responses.

Table 6.19 Descriptive statistics of ASCI V2 for Biochemistry class

Item #	Biochemistry, N=88		Mean	SD
1r	easy	hard	3.25	1.24
2	complicated	simple	3.43	1.55
3	confusing	clear	3.89	1.40
4r	comfortable	uncomfortable	4.06	1.38
5r	satisfying	frustrating	3.84	1.56
6	challenging	unchallenging	2.84	1.57
7r	pleasant	unpleasant	3.82	1.42
8	chaotic	organized	4.51	1.46

Note: Item score is reversed before averaging.

Each score should range from 1 to 7, and 4 is in the middle point. Higher score means students feel chemistry is intellectually accessible, emotional satisfying. Item 2 has the highest mean of 4.55, and item 6 has the lowest mean of 2.84, which indicates they feel chemistry is organized, and is challenging.

Internal consistencies were calculated for each subscale using the listwise deletion (Table 6.20). For the Biochemistry results, Cronbach's alpha was .78 and .81 for the 2 subscales, which was above satisfactory level .70, and comparable to the literature results.

An exploratory factor analysis was performed using strategy **B** (principal axis factor analysis methods and Promax). Two factors were extracted. Item loadings for each item are listed in Table 6.21. All items were loaded well on the assumed factors.

Table 6.20 Internal consistency for V2 in Biochemistry class

ASCI, V2	Cronbach's alpha		
Scale and item	Biochemistry (N=95)	PL (n=354)	Literature(Bauer, 2008), v1
Intellectual accessibility (1,2,3,6)	.79	.82	.78 ^a
Emotional satisfaction (4,5,7,8)	.81	.79	.79

^a In ASCI V1, Intellectual accessibility has five items.

Table 6.21 The item loadings of V2 for Biochemistry and PL classes

Item # in each scale			Loading Biochemistry		Loading PL	
			F1	F2	F1	F2
Intellectual accessibility			N=88		N=354	
1r ^a	easy	hard	0.32	0.42	0.41	0.66
2	complicated	simple	-0.17	1.07	0.34	0.75
3	confusing	clear	0.37	0.47	0.45	0.68
6	challenging	unchallenging	0.07	0.53	.00	0.86
Emotional satisfaction						
4r	comfortable	uncomfortable	0.75	0.08	0.74	0.29
5r	satisfying	frustrating	0.75	0.08	0.72	0.36
7r	pleasant	unpleasant	0.75	0.08	0.75	0.38
8	chaotic	organized	0.40	0.00	0.71	0.02

EFA is performed in SPSS 17.0. Strategy **B** was used including principal axis factor analysis methods and Promax rotation using the covariance matrix. 2 factors are extracted for comparison. Item loadings on the assumed factors are highlighted in bold.

r^a: negatively stated

Factor scores created by sum of item score and factor correlations are listed in Table 6.22

Attitude scores of Biochemistry students were only compared with Peer-led classes and Peer-leaders. Scores on ASCI V3 was not listed because 2-factor structure was not confirmed. Attitude score for Biochemistry students was 3.36 for Intellectual accessibility and 4.09 for emotional satisfaction, with a correlation of .54 between them. Factor correlation was similar with V2 of Peer-led classes, which indicates the factor functions similarly across different populations. Attitude score for Biochemistry students was higher than PL classes in both scales. Because enrollment in the Biochemistry prerequisites the minimum grade of “C” in General Chemistry I and II, Organic Chemistry I and II, and Biology, the result reflected our expectation that Biochemistry students with more chemistry expertise held a more positive attitude (effect size is about .3). Peer leaders were most satisfied with chemistry, and they scored the highest on both scales.

Table 6.22 Factor score and Pearson correlations for PL and Biochemistry class

ASCI, V2	Biochemistry (n=88)		PL student (n=354)		Peer leader (n=12)	
	Access	Emotion	Access	Emotion	Access	Emotion
Mean	3.36	4.06	2.91	3.62	4.27	4.58
SD	1.13	1.17	1.13	1.20	1.66	2.01
Factor	correlation					
Intellectual access	0.54		0.64		0.33(n.s.)	

CFA was performed to estimate goodness of fit of the 2-factor model. The items were set to load on its assumed factor only. The estimation of the 2-factor model fit for the Biochemistry class was (Table 6.23): χ^2 (N = 88, df = 19, p = .059) = 29.5, which failed to reject the null hypothesis of a good fit. Since CFI was greater than .95, RMSEA was less than .08 and SRMR was less than .08, the overall model fit the data pretty well.

Factor correlation from CFA between the "intellectual accessibility" and "emotional satisfaction" was .67, which suggests the strong correlation for the two components and consistent with previous findings (r: .80).

Table 6.23 Fit statistics of V2 results from two-factor CFA

Fit Statistic	Value	
	Biochemistry	PL
χ^2	29.5	77.0
df	19	19
p	.059 (n.s.)	.00
N	88	354
CFI	.96	.95
RMSEA	.079	.093
SRMR	.050	.042

Note: χ^2 = Chi-square, df = degree of freedom, N = sample size, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square Residual

Summary

The above results evaluated reliability and construct validity of ASCI V2 data from two groups of students enrolled in PL and Biochemistry classes. For these eight items on the survey, the two factor structure (intellectual accessibility and emotional satisfaction) is supported by CFA for V2 results, but not for V3 and V3.1 results.

Chapter Seven

Summary and Concluding Discussion

Summary and Implications for Chemical Education

Starting with the original ASCI (V1) developed by Bauer, we designed and implemented a process of scale development to refine the instrument for better construct validity.

Better construct validity results in greater ease of interpretation, which we demonstrated via an examination of a nomological network and predictive validity for ASCI V2. The research questions were successfully answered.

Research question one was to evaluate psychometric quality for the responses from ASCI V1 in terms of reliability and validity. ASCI V1 results showed a similar data pattern with the literature, and the construct validity of ASCI V1 scores was not supported by confirmatory factor analysis.

Research question two was to propose modified versions of ASCI based on factor analysis and attitude theoretical framework. Starting from the 20-item ASCI, we deleted redundant items and scales, reconstructed meaningful subscales and estimated the data fit to theoretical models. Several methodological issues were clarified here. For example, confirmatory factor analysis was used as the most rigorous test for whether the internal data structure matches the conceptual framework. Additionally, factor scores were suggested for use when there is more than one factor among the measured data set, with only those items loading on the same construct used to determine the factor score. In general, the investigator has tried to showcase ways in which evidence for reliability and

validity of instrument scores can be provided so readers can interpret and apply research findings with a certain degree of confidence. This work represents the first time in the area of chemical education that a benchmark for scale development was successfully implemented to reconstruct an existing instrument.

Research question three was to evaluate psychometric quality for the responses from revised ASCI (V2, V3 and V3.1) in terms of reliability and validity. ASCI V2 was designed to measure two subscales of attitude: intellectual accessibility and emotional satisfaction. These two subscales are indicators of cognition and of affect, respectively, and thus make a good connection with the conceptual framework for attitude from psychology. Evidence for construct validity was obtained. The two-factor correlated structure was upheld by confirmatory factor analysis. As regards to correlations among attitude, achievement and ability, attitude correlates with SATM, ACTM, and ACS scores as expected, which provides evidence for a nomological network validity. Finally, once aptitude ability is taken into account, a component of attitude measured by ASCI V2 plays a significant unique part in predicting final achievement in General Chemistry I Peer-led students.

The two-factor correlated structure of ASCI V2 was further replicated for biochemistry students. The score of ASCI could discriminate different student cohorts, as supported by the more positive attitudes held by students in Biochemistry course with more advanced understanding of chemistry than those in General Chemistry I course.

Construct validity of ASCI V3 and V3.1 score was not confirmed by CFA.

This study contributes to chemical education research by providing validity evidence for a revised instrument, ASCI V2, for college chemistry students. In addition to showcasing

a method for examining validity, a second important result of this work is to recommend refinements that lead to greater ease of administration while improving validity: this eight item instrument now takes very little time to administer. Because of its convenience and high psychometric quality, chemistry educators who are interested in determining students' attitudes towards chemistry can easily find time to administer ASCI V2, even to a large class, and can expect the results to be interpretable.

Limitations of the Study and Recommendations for Future Research

We envision a significant potential use of ASCI V2 will be to identify the effects of curricular reforms, via experimental or quasi-experimental designs. Using ASCI V2 as a pre- and post-test for treatment and comparison groups would allow the effect of course experience on the attitude change of each student to be tracked. In addition, this type of study could provide further evidence for validity which we were not able to provide here, by exploring attitude change directly with the same sample of students on the same measure, and by exploring whether the two factors relate to curricular intentions in an expected way.

It is not the case that ASCI (V2) captures all potential aspects of attitude, nor that a single measure is desirable. Exploration of attitude theory and past research practice involve both a variety of quantitative assessments (Table 6.6 is but a small subset) and of qualitative investigations. Understanding how ASCI V2 fits into this complex set of possibilities can only be accomplished by further examining its relationships with other measures of attitude, achievement, and additional constructs such as learning strategies, motivation, and behavior.

Ultimately, since we as chemical educators are increasingly asked to utilize assessment within our classrooms, we have a great need for easy-to-use instruments that yield valid, reliable, and readily interpretable scores for constructs of interest. We hope that, in the classes of our collective community, students' attitudes toward chemistry are becoming more rather than less positive, and also that ASCI V2 will help us all to investigate the truth of that proposition.

Since the similar pattern of chemistry and calculus students responded to ASCI V3 and V3.1, it is worthwhile to create the version V2.1 (by changing the word of chemistry into calculus) to calculus classes. If it functions well with calculus, possibly we can give more derivative versions to other science subjects like physics. However, it remains a challenge because people may use different adjectives to describe their attitude towards different subjects, which necessitates the some new items from scratch and cognitive interview.

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Appendices

Appendix A: Commonly Used Acronyms

University MW: a large Middle West Public Research University
University SE: a large Southeastern Public Research University
PL: Peer-Led Guided Inquiry
SAT Math: SATM, math portion of the SAT exam
ACT math: ACTM, math portion of the ACT exam
ACS: American Chemical Society
ACS Exam: American Chemical Society First Semester General Chemistry (Special) Examination
Sk: Skewness, a measure of symmetry of the probability distribution
Ku: Kurtosis, a measure of "peakedness" (peaked or flat) of the probability
n: sample size
M: mean
SD: standard deviation
EFA: exploratory factor analysis
CFA: confirmative factor analysis

Appendix B: ASCI VI

Name: _____ U**-ID _____ lab section: _____

A list of opposing words appears below. Rate how well these words describe your feelings about **chemistry**. Think carefully and **try not to include** your feelings toward chemistry teachers or chemistry courses. For each line, choose a position between the two words that describes **exactly how you feel**. Circle that number on this sheet. The middle position is if you are undecided or have no feelings related to the terms on that line. When you are done with all 20 items, also record your responses on the scantron. (B=1, C=2, D=3, E=4, F=5, G=6, H=7)

CHEMISTRY IS

1	easy	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	hard
		middle	
2	worthless	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	beneficial
3	exciting	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	boring
4	complicated	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	simple
5	confusing	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	clear
6	good	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	bad
		middle	
7	satisfying	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	frustrating
8	scary	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	fun
9	comprehensible	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	incomprehensible
10	challenging	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	not challenging
11	pleasant	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	unpleasant
		middle	
12	interesting	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	dull
13	disgusting	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	attractive
14	comfortable	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	uncomfortable
15	worthwhile	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	useless
16	work	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	play
		middle	
17	chaotic	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	organized
18	safe	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	dangerous
19	tense	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	relaxed
20	insecure	<input type="text"/> 1 <input type="text"/> 2 <input type="text"/> 3 <input type="text"/> 4 <input type="text"/> 5 <input type="text"/> 6 <input type="text"/> 7 <input type="text"/>	secure

Appendix C: ASCI V2

Name: _____ U**-ID: _____ Section: _____

A list of opposing words appears below. Rate how well these words describe your feelings about **chemistry**. Think carefully and **try not to include** your feelings toward chemistry teachers or chemistry courses. For each line, choose a position between the two words that describes **exactly how you feel**. Circle that number on this sheet. The middle position is if you are undecided or have no feelings related to the terms on that line.

When you are done with all 8 items, also record your responses on the scantron (B=1, C=2, D=3, E=4, F=5, G=6, H=7). **Make sure to bubble in your name and U**-ID.**

CHEMISTRY IS

1	easy	_1_ _2_ _3_ _4_ _5_ _6_ _7_	hard
		middle	
2	complicated	_1_ _2_ _3_ _4_ _5_ _6_ _7_	simple
3	confusing	_1_ _2_ _3_ _4_ _5_ _6_ _7_	clear
4	comfortable	_1_ _2_ _3_ _4_ _5_ _6_ _7_	uncomfortable
5	satisfying	_1_ _2_ _3_ _4_ _5_ _6_ _7_	frustrating
6	challenging	_1_ _2_ _3_ _4_ _5_ _6_ _7_	not challenging
7	pleasant	_1_ _2_ _3_ _4_ _5_ _6_ _7_	unpleasant
		middle	
8	chaotic	_1_ _2_ _3_ _4_ _5_ _6_ _7_	organized

Appendix D: ASCI V3

Name: _____ U**-ID: _____ Peer Leader: _____

A list of opposing words appears below. Rate how well these words describe your feelings about **chemistry**. Think carefully and **try not to include** your feelings toward chemistry teachers or chemistry courses. For each line, choose a position between the two words that describes **exactly how you feel**. Circle that number on this sheet. The middle position is if you are undecided or have no feelings related to the terms on that line.

When you are done with all 8 items, also record your responses on the scantron (B=1, C=2, D=3, E=4, F=5, G=6, H=7). **Make sure to bubble in your name and U**-ID.**

CHEMISTRY IS

1	easy	_1_ _2_ _3_ _4_ _5_ _6_ _7_	hard
		middle	
2	chaotic	_1_ _2_ _3_ _4_ _5_ _6_ _7_	organized
3	confusing	_1_ _2_ _3_ _4_ _5_ _6_ _7_	clear
4	comfortable	_1_ _2_ _3_ _4_ _5_ _6_ _7_	uncomfortable
5	satisfying	_1_ _2_ _3_ _4_ _5_ _6_ _7_	frustrating
6	challenging	_1_ _2_ _3_ _4_ _5_ _6_ _7_	not challenging
7	pleasant	_1_ _2_ _3_ _4_ _5_ _6_ _7_	unpleasant
		middle	
8	complicated	_1_ _2_ _3_ _4_ _5_ _6_ _7_	simple

Appendix E: ASCI V3.1

Name: _____ U**-ID: _____ Instructor: _____

A list of opposing words appears below. Rate how well these words describe your feelings about **calculus**. Think carefully and **try not to include** your feelings toward calculus teachers or calculus courses. For each line, choose a position between the two words that describes **exactly how you feel**. Circle that number on this sheet. The middle position is if you are undecided or have no feelings related to the terms on that line. When you are done with all 8 items, also record your responses on the scantron (B=1, C=2, D=3, E=4, F=5, G=6, H=7). **Make sure to bubble in your name and U**-ID.**

CALCULUS IS

1	easy	_1_ _2_ _3_ _4_ _5_ _6_ _7_	Hard
		middle	
2	chaotic	_1_ _2_ _3_ _4_ _5_ _6_ _7_	organized
3	confusing	_1_ _2_ _3_ _4_ _5_ _6_ _7_	Clear
4	comfortable	_1_ _2_ _3_ _4_ _5_ _6_ _7_	uncomfortable
5	satisfying	_1_ _2_ _3_ _4_ _5_ _6_ _7_	frustrating
6	challenging	_1_ _2_ _3_ _4_ _5_ _6_ _7_	Not challenging
7	pleasant	_1_ _2_ _3_ _4_ _5_ _6_ _7_	unpleasant
		middle	
8	complicated	_1_ _2_ _3_ _4_ _5_ _6_ _7_	simple