THINKING ABOUT ONLINE SOURCES: EXPLORING STUDENTS’ EPISTEMIC COGNITION IN INTERNET-BASED CHEMISTRY LEARNING

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ABSTRACT

This dissertation investigated the relation between epistemic cognition—epistemic aims and source beliefs—and learning outcome in an Internet-based research context. Based on a framework of epistemic cognition (Chinn, Buckland, & Samarapungavan, 2011), a context-specific epistemic aims and source beliefs questionnaire (CEASBQ) was developed and administered to 354 students from college-level introductory chemistry courses. A series of multitrait-multimethod model comparisons provided evidence for construct convergent and discriminant validity for three epistemic aims—*true beliefs*, *justified beliefs*, *explanatory connection*, which were all distinguished from, yet correlated with, mastery goals. Students' epistemic aims were specific to the chemistry topics in research. Multidimensional scaling results indicated that students' source evaluation was based on two dimensions—*professional expertise* and *first-hand knowledge*, suggesting a multidimensional structure of source beliefs. Most importantly, online learning outcome was found to be significantly associated with two epistemic aims—justified beliefs and explanatory connection: The more students sought justifications in the online research, the lower they tended to score on the learning outcome measure, whereas the more students sought explanatory connections between information, the higher they scored on the outcome measure. There was a significant but small positive association between source beliefs and learning outcome. The influences of epistemic aims and source beliefs on learning outcome were found to be above and beyond the effects of a number of covariates, including prior knowledge and perceived ability with online sources.

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I dedicate my dissertation to my dearest grandfather. To grandpa, you always loved me, supported me, understood me, and believed in me. I was never able to say this to you, but I have never stopped striving to accomplish it: I will be a great researcher and a great person, just like you.

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CHAPTER 1. INTRODUCTION

Learning has been transformed in the Information Age. Computers, smart mobile devices, Internet, and other advanced technologies have enriched the learning tools at our disposal to accelerate learning. Individuals have increased access to information available in different forms of media (e.g., the Internet and mass media), in addition to traditional sources (such as teachers, textbooks, and experienced others), which removes a number of constraints for learning. With the advancement of Internet technologies, information of varied quality has become more and more readily available on the Internet.

These advanced technologies have also posed challenges for learning. Individuals often lack adequate cognitions needed for finding, evaluating, selecting, and applying sources of knowledge among information on the Internet and other media (Alexander & Disciplined Reading and Learning Research Laboratory, 2012; Priemer & Ploog, 2007). This problem involves individuals' epistemic cognition, specifically in the context of using the Internet for learning purposes. Epistemic cognition, or personal epistemology, refers to individuals' thinking about the nature of knowledge and the process of knowing (Hofer & Pintrich, 2002). These cognitions have a critical effect on how people approach learning and on what they learn (Elby & Hammer, 2010). Epistemic cognition therefore plays an important role in individuals' learning in the Internet-based context, especially in terms of how they approach sources and what they obtain from sources.

Early Theories of Epistemic Cognition

Epistemic cognition, or personal epistemology, originates from *epistemology*, a field of interest in philosophy that concerns the nature and scope of human knowledge. Educational psychologists define personal epistemology as individuals' thinking about knowledge and knowing, and focus particularly on personal epistemology in relations to learning and achievement (Hofer & Pintrich, 2002).

Philosophical Origins

Epistemology, or the theory of knowledge, is a branch of philosophy that studies the scope and nature of knowledge and rational belief (BonJour, 2010). The traditional philosophical analysis of knowledge defines *knowledge* as sufficiently justified true belief, which denotes that for a person to have factual knowledge the known has to be true, the person has to believe the known, and the person has to have an adequate basis for believing it. The main topics of study in epistemology include knowledge, justification, truth, and the possibility of error. There is overlapping territory between epistemology and psychology, especially in studying the purported source of knowledge (Conee & Feldman, 2006). However, unlike psychological epistemology research, epistemology in philosophy does not concern why people hold certain beliefs that they do or how people come to hold the beliefs that they do (Hamlyn, 2006).

Psychological Studies of Epistemic Cognition

The psychological studies of epistemology can be traced back to the 1950s, when Piaget studied *genetic epistemology*—the emergence and development of children's process of knowing and organization of knowledge (Piaget, 1952). Unlike most of the philosophers, who use logical arguments to develop their theories, Piaget investigated epistemology with formulated hypotheses and scientific investigation methods, and found that the knower and the known form an active relationship in the process of knowing: children's knowledge develops as their cognitive system matures, therefore, as the knower changes, her knowledge of the world also changes (Miller, 2002). Piaget's works on epistemological development built the groundwork for psychological studies of personal epistemology in terms of methodology and theory.

Psychological research on personal epistemology focuses on how individuals develop, interpret, justify, and evaluate knowledge, and how these subjective conceptions about knowledge and knowing are associated with reasoning, learning processes, and academic achievement (Hofer & Bendixen, 2012). There have been three main paradigms of psychological research on personal epistemology—*epistemological development* (Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; Patricia M. King & Karen Strohm Kitchener, 1994; Kuhn, Cheney, & Weinstock, 2000; Perry, 1970), *a system of beliefs with multiple dimensions* (Greene, Azevedo, & Torney-Purta, 2008; Hofer & Pintrich, 1997; Schommer, 1990), and *epistemological resources* (Elby & Hammer, 2001; Hammer & Elby, 2002; Louca, Elby, Hammer, & Kagey, 2004). Although they approach personal epistemology from different perspectives, these paradigms of research have greatly enriched and deepened our understandings about the nature and scope of this construct.

The foundational work on epistemological development is by Perry (1970). Depending heavily on Piaget's conceptual framework of assimilation and accommodation (Piaget, 1952), Perry designed his research to document the experience of undergraduates at Harvard University and to trace the development of the forms in which these students perceived their educational experiences. The researcher found a great variety of student responses to the relativist intellectual atmosphere of the university, and, consequently, various ways to assimilate such experience. Perry's work (1970) on intellectual and ethical development was widely acknowledged as the pioneer research attempt on personal epistemology (Hofer & Pintrich, 1997; Moore, 2002). Most of the research in the developmental paradigm was built on Perry's theory. Belenky and colleagues aimed to enhance the generalizability of Perry's theory to the women knowers in their studies of women's way of knowing (Belenky et al., 1986). Baxter Magolda's empirical work set out to quantify Perry's scheme of knowing with her Measure of Epistemological Reflection (MER; Baxter Magolda, 1992; Baxter Magolda, 2002). In King and Kitchener's Reflective Judgment Model (King & Kitchener, 2004; Kitchener, 1983), the researchers also adopted Perry's work on relativism, in addition to Dewey's theory about reflective thinking (Dewey, 1933, 1938), as the theoretical groundwork. The shared theoretical foundation of this line research sets a common starting point for the developmental paradigm.

Arguably the most widely used framework of multidimensional epistemic beliefs is Hofer and Pintrich (1997). In their comprehensive review and synthesis of the prior research on personal epistemology, Hofer and Pintrich pointed out the theoretical and methodological issues existing in the field, and proposed a newer multidimensional model of beliefs about knowledge and knowing. They clarified issues on the definition of the construct and the dimensionality of epistemological beliefs, and contended that there is a developmental pattern for personal epistemological beliefs that is not solely determined by ages, but also cognitive development and education. They also laid out how individuals acquire epistemological awareness and how epistemological beliefs change, and addressed other related methodological issues.

Hofer and Pintrich (1997) proposed that epistemological beliefs comprise two dimensions that tap the nature of knowledge—*certainty of knowledge* and *simplicity of* *knowledge*, and the other two dimensions that entail the nature of knowing—*source of knowledge* and *justification for knowing*. Each of the four dimensions is a continuum. Simplicity of knowledge is a continuum developing from believing absolute truth exists to believing knowledge is evolving. Certainty of knowledge denotes a continuum developing from believing knowledge is discrete and concrete to believing knowledge is relative, contingent and contextual. Source of knowledge is a continuum with the lower-level view that knowledge exists outside of oneself from external authority and the higher-level view that knowledge is constructible by oneself and in the interaction with others. Justification for knowing refers to individuals' beliefs about how knowledge claims are justified, which is a continuum with the lower-level view of dualist beliefs and the higher-level view of multiplistic acceptance of opinions to reasoned justification.

To test the dimensions proposed by Hofer and Pintrich (1997), Hofer (2000) used questionnaires on domain-specific epistemological beliefs with a sample of 327 college freshmen enrolled in an introductory psychology course. Exploratory factor analyses indicated four factors: 1) *certain/simple knowledge*, 2) *justification for knowing: personal*, 3) *source of knowledge: authority*, and 4) *attainability of truth*. Simplicity and certainty of knowledge, two distinct dimensions proposed by Hofer and Pintrich (1997) were merged to be one factor, and the fourth factor, attainability of truth, was not hypothesized. Hofer argued that simplicity and certainty might not be two independent dimensions but instead represent one group of beliefs, or that they might be conceptually understood as two dimensions but operate as one dimension. In regard to the unhypothesized factor, attainability of truth, it appeared as a distinct factor from certainty because it did not significantly load with the certainty items (Hofer, 2000). Nonetheless, the existence of this merged dimension has not consistently been confirmed in empirical studies on different populations or in different subject domain (e.g., Bråten et al., 2005, Strømsø & Bråten, 2010). The ambiguity in the factor structure requires further examination of the construct validity for measurement of epistemological beliefs.

Hofer and Pintrich (1997) proposed that “the content of the construct of epistemological beliefs be limited to individuals’ beliefs about the nature of knowledge and the processes of knowing” (p.117), which excluded beliefs about learning, intelligence, and teaching from the scope of personal epistemology, while recognizing the relations between these beliefs and epistemological beliefs. Hofer and Pintrich’s (1997) model differed from Schommer-Aikins’s (1991) model in that they clarified the scope of epistemology being directly related only to beliefs about the nature of knowledge and the processes of knowing and hence excluded beliefs about learning, and thinking from their model. Their model also captured an important concept of the beliefs about the processes of knowing—justifications for knowing. Although they did not describe the dimension beyond Perry’s framework (i.e., from *dualism* to *rationalism*), this dimension, which was never in any way described by the prior theories, enriches Hofer and Pintrich’s model by including an explicit account for beliefs about the process of knowing.

There is a rather different school of theories on epistemic cognition—*epistemological resources*—which conceptualize epistemic cognition as activated in context rather than stable, trait-like beliefs (Elby & Hammer, 2001). Pointing out that frameworks of developmental stages and beliefs about knowledge fail to attend to contextual elements, the researchers proposed a rather different conceptualization of personal epistemology—epistemological resources (Hammer & Elby, 2002; Louca et al., 2004), which emphasized the finer-grained, more context-specific nature of epistemology than stages, beliefs, or theories. Specifically, the knower has cognitive resources for viewing knowledge as transmitted (i.e., *knowledge as transmitted stuff*) and for viewing it as constructed (i.e., *knowledge as fabricated stuff)*. Different contexts trigger the activation of different cognitive resources. In other words, a learner can deem knowledge originated from outside sources or constructed by herself, but a specific context may activate epistemological resources for her to view knowledge as achieved in one way or another (or in both ways). This conceptualization framework helps scrutinize personal epistemology in different contexts rather than making inference about individuals' beliefs from measurement in a single context. It is reasonable to compare context-dependent epistemological resources and to summarize their consistency and stability across multiple contexts in order to make general inferences about beliefs (Louca et al., 2004).

Context-Specific Epistemic Cognition

Although prior research on epistemic cognition has advanced our understandings about the construct, there are still mixed results on how epistemic cognition figures into a learning process, especially about prediction of learning behavior and outcomes in a specific context (Bråten, Strømsø, & Samuelstuen, 2008). In recent theoretical work, Chinn and colleagues proposed an *expanded framework of epistemic cognition* based on both current psychological studies and philosophical research on epistemology (Chinn, Buckland, & Samarapungavan, 2011). This expanded model of epistemic cognition not only introduced into psychological research a number of important components of personal epistemology, but also emphasized the context specificity and a more fine-grained unit of analysis for personal epistemology. This framework provides an ideal theoretical foundation for the study of epistemic cognition in Internet-based contexts.

Chinn and colleagues (2011) proposed an expanded framework of interconnected epistemic cognitions including epistemic aims, epistemic value, cognition about the structure of knowledge, beliefs about source of knowledge, beliefs about justification, epistemic virtues and vices, and beliefs about reliable vs. unreliable processes of achieving epistemic aims. The framework can enhance the scope of research on epistemic cognition from the widely researched dimensions (e.g., structure of knowledge, beliefs about source, and beliefs about justification) to a more comprehensive model of these epistemic cognitive processes. In addition, Chinn and colleagues (2011) have taken innovative perspectives on the structure of and sources of knowing, and justifications for knowledge in hopes of addressing theoretical issues that prior research has not succeeded in resolving. In particular, Chinn and colleagues reinstated *external sources* (as opposed to *personal experiences*) as one of the many important sources for knowledge acquisition, and proposed the term *testimony* as a replacement for *authority* to avoid biased interpretation of this type of sources.

What makes Chinn et al.'s (2011) framework of epistemic cognition ideal to guide research on epistemic cognition in Internet-based learning is the emphasis on context specificity of epistemic cognition and its ability to predict situation-specific learning behavior and outcomes. Each component in this framework has context specificity to different degrees. For instance, epistemic aims—goals of finding things out in the processing of knowing—are context specific, largely due to the fact that individuals adopt different aims in different situations. In online research, students may adopt different epistemic aims for research topic 1 than for research topic 2; for the same research topic, students may adopt different epistemic aims for online research due to different contextual factors, such as whether it is a timed task vs. an untimed task, and the larger learning goals, such as mastery vs. performance goals. Similarly, students' epistemic cognition about sources may also depend on the context (e.g., online source availability, knowledge about particular sources). These context-specific epistemic cognitions shed light on the learning behavior and outcomes in the learning context. As such, a finer-grained, context-specific examination of epistemic cognition may provide knowledge about individuals' learning in context, which may not be understood otherwise.

Another reason for adopting Chinn et al.'s model (2011) as the theoretical framework for studying epistemic cognition in Internet-based learning concerns the intense burden on the learner in the online context of source identification, evaluation, selection, and application. In order to efficiently complete the learning tasks online, the learner needs to develop adaptive epistemic cognitions, especially in terms of setting aims for acquiring knowledge from the online sources (*epistemic aims*) and holding source beliefs that effectively guide online source evaluation and selection (*source beliefs*). Chinn et al.'s framework explicitly theorizes epistemic aims as the central component in epistemic cognition and hypothesizes that epistemic aims consist of at least three dimensions—true vs. false beliefs, sufficiently vs. minimally justified beliefs, and acquiring explanatory connections vs. a collection of isolated facts. These epistemic aims may help students orient their learning activities when processing the abundant information on the Internet. Furthermore, prior research has shown that students engage in both epistemic and non-epistemic online learning activities and hold both epistemic and non-epistemic beliefs (List, Grossnickle, Loyens, & Alexander, 2013, April; Mason, Boldrin, & Ariasi, 2010b). Students' epistemic aims determine whether other cognitive processes involved in Internet-based learning are related to knowledge and knowing (i.e., of an epistemic nature). Chinn et al.'s (2011) framework highlights the necessity of investigating epistemic aims, which is of utmost importance to understanding epistemic cognition in Internet-based learning.

If we assume that Internet-based learning involves a substantial amount of source searching and evaluation, then it is crucial for students to hold adaptive epistemic beliefs about sources and to use them as guidance in the process of identifying, evaluating, and selecting sources of knowledge. Existing theories about source beliefs that scale these beliefs with levels of sophistication (i.e., resorting to authority for knowledge is a naïve source belief, and engaging in personal experimentation for knowledge is a sophisticated source belief) are too coarse and, perhaps, even misleading for accurate assessment of source beliefs in Internet-based learning. Chinn et al. (2011) stressed *testimony* (i.e., external sources or claims of others) as a correct and necessary type of source of knowledge in addition to perception, introspection, memory, reasoning, and experimentation. Resorting to testimony as a type of source for knowledge acquisition is consistent with the purpose of online research and Internet-based learning, because if resorting to testimony (or "authority" as other researchers call it) is considered a naïve or ineffective epistemic belief for learning, then any online research for knowledge would be pointless, for most online sources are external sources or testimonies for Internet users. Human knowledge relies heavily on testimony as a social source of knowledge, and acquiring knowledge from testimony on the Internet certainly should be conceptualized as a valid means of learning as proposed by Chinn et al. (2011).

The Importance of Epistemic Cognition to Internet-Based Learning

Epistemic cognition is of utmost importance in Internet-based learning (Barzilai & Zohar, 2012; L. Mason & Boldrin, 2008; Porsch & Bromme, 2011). Skilled Internet-based learners are better at evaluating the credibility and reliability of sources (Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012), which implies that adaptive epistemic cognition about sources is essential in Internet-based learning. Research has identified a number of epistemic cognition dimensions that are prevalent in students' Internet-based learning (Chiu, Liang, & Tsai, 2013; Mason et al., 2010b; Strømsø & Bråten, 2010), including beliefs about the nature of knowledge (or certainty and simplicity of knowledge; Bråten & Strømsø, 2006; Kienhues, Stadtler, & Bromme, 2011), beliefs about justification (Bråten, Ferguson, Strømsø, & Anmarkrud, 2013; Ferguson, Bråten, & Strømsø, 2012), and the most widely-found source beliefs, such as relying on authority-type sources for knowledge (Goldman, 2011; Halverson, Siegel, & Freyermuth, 2010; List et al., 2013, April; Madden, Ford, Gorrell, Eaglestone, & Holdridge, 2012; Strømsø, Bråten, & Britt, 2011). These dimensions of epistemic cognition influence students' Internet-based learning in terms of online text comprehension (Bråten et al., 2008; Goldman et al., 2012) and integration of multiple texts (Bråten, Britt, Strømsø, & Rouet, 2011), information synthesis (Mason et al., 2010b), problem solving (Goldman, 2011), decision making (Kienhues et al., 2011), strategy use (Barzilai & Zohar, 2012; Bråten & Strømsø, 2006; Bråten, Strømsø, & Samuelstuen, 2005), self-regulated learning (Chiu et al., 2013), and Internet-based information evaluation (Kammerer, Bråten, Gerjets, & Strømsø, 2013; Wiley et al., 2009).

Amongst the components of epistemic cognition, source beliefs and epistemic aims appear to be the most important in Internet-based learning. In their review of research on reading and learning online, Alexander and associates (Alexander & Disciplined Reading and Learning Research Laboratory, 2012) point out that a competent reader in the 21st century needs to continuously develop expertise and adaptive epistemic cognition. In particular, reading and learning in the Internet contexts require the reader to "…respond flexibly and appropriately to the demands of a given text or texts processed for some purpose within a particular time and place" (p. 270), which highlights a few key aspects of adaptive epistemic cognition as defined by Chinn and colleagues (2011). These include the abilities to reflect on the nature of knowledge, establish criteria for knowing, and evaluate and validate knowledge claims, with a clear goal of achieving specific accomplishments in the context of Internet-based learning.

The first three aspects all involve adaptive epistemic beliefs about sources of knowledge. The specific accomplishments that are set as goals could include epistemic aims (e.g., 'I want to attain true beliefs), and in the case of Internet-based learning, such aims are often necessary for learning to proceed effectively. Therefore, it appears that in Internet-based learning, epistemic aims may play a role of directing and guiding online research, reading, and learning. In addition, source beliefs are *essential* for the process of Internet-based learning, and to a large extent determine the quality of online research and reading, as well as learning outcomes. Epistemic aims may lead to different thinking about the online sources; source beliefs may, in turn, influence to what extent a learner can achieve her epistemic aims in Internet-based learning. The mutual influence between these components of epistemic cognition—epistemic aims and source beliefs—may manifest in Internet-based learning and together affect the learning process and outcomes.

Chinn and colleagues' (Chinn et al., 2011) framework of epistemic cognition seamlessly fits into the study of epistemic cognition in Internet-based learning. First, the construct of epistemic aims has been posited as taking a central position in epistemic cognition and has been emphasized as one of the most important components of epistemic cognition to study. In order to know whether the cognitive processes captured by a measure are of an epistemic nature, one needs to first understand whether students set aims for epistemic achievements. This framework provides a solid theoretical foundation for me to study epistemic aims in this dissertation.

According to Alexander and associates (Alexander & Disciplined Reading and Learning Research Laboratory, 2012), reading and learning on the Internet is a goal-directed activity. To understand Internet-based learning, it is essential to understand these goals, which may include epistemic aims. Second, one of the competences for reading on the Internet is adaptive epistemic cognition, especially, adaptive source beliefs (Alexander & Disciplined Reading and Learning Research Laboratory, 2012), which is one of the rationales for me to study source beliefs specifically, of the many components of epistemic cognition. Chinn et al. (2011) proposed that individuals resort to multiple sources for knowledge and that people hold specific criteria for source of knowledge. These innovative views regarding source beliefs fit the context of Internet-based learning, because students have access to numerous different sources online for information, and the multiple-sources-of-knowledge proposal provides a theoretical foundation for me to study students' source beliefs in this context. In addition, these new viewpoints on source are rather different from prior theories (e.g., Hofer, 2000), and therefore, should be tested in empirical research, in order to further our understanding about individuals' source beliefs in Internet-based learning.

Objectives and Significance of this Dissertation

In response to Chinn and colleagues' (Chinn et al., 2011) call for validating the components of context-specific epistemic cognition and examining the relations between epistemic cognition and learning outcomes in a particular context, I investigated epistemic aims and source beliefs in a simulated Internet-based learning context, in which college students conducted online research on three chemistry topics—the danger of antifreeze, corrosion of iron, and heartburn. There are five main goals I set out to accomplish with this dissertation study: first, I aimed to validate the construct of multidimensional epistemic aims. Second, I set out to further our understanding of epistemic beliefs about sources of knowledge. Third, I aimed to study whether students' epistemic aims and source beliefs are specific to learning contexts. Fourth, I sought to develop a context-specific self-report measure of epistemic aims and source beliefs to contribute to the methodological improvement for assessing epistemic cognition. Fifth, I aimed to investigate the relations between epistemic cognitions (i.e., epistemic aims and source beliefs) and learning outcomes in the online research on three chemistry topics.

Validating Epistemic Aims

As theorized in Chinn et al. (2011), there are at least three types of epistemic aims: the learner seeks to obtain true versus false beliefs, to obtain sufficiently versus minimally justified beliefs, and to obtain explanatory connections of facts versus a collection of disconnected facts. In the dissertation study, I aimed to survey the prevalence of setting epistemic aims by the learners, and to validate the construct of multidimensional epistemic aims with the three dimensions above mentioned. The validation of multidimensional epistemic aims will contribute to the literature on epistemic cognition (or personal epistemology) in terms of expanding the scope of research on epistemic cognition and further supporting multidimensionality of epistemic cognition.

The concept of *epistemic aims* may to a large degree resembles *mastery goals* in achievement goal theory (Ames, 1992a, 1992b; Elliot & McGregor, 2001). In an attempt to validate epistemic aims—true beliefs, sufficiently justified beliefs, and explanatory connections, I sought evidence that supports the construct discriminant validity of this new construct by differentiating epistemic aims from mastery goals. By studying both epistemic aims and mastery goals, I have been able to find out the relationships between the two constructs, and contribute to the literature in terms of how mastery goals and epistemic aims are positioned in the general framework of goals.

Furthering Understanding of Source Beliefs

Chinn et al. (2011) argued for the importance of testimony and multiple sources in processes of knowledge acquisition. In this dissertation study, I set out to explicitly investigate whether students turn to multiple sources for knowledge, whether or not they critically evaluate sources, what standards they set for a source to develop new beliefs and what standards they set for a source to refute held beliefs about a topic. Furthermore, I sought to understand whether students’ source beliefs are related to their self-perceived competence with processing different sources. The renewed knowledge about individuals' source beliefs will correct some of the misconceptions about source beliefs (in particular, that believing in authority-type sources for knowledge is a naïve epistemology), support the importance of epistemic criteria for sources as found in prior research (e.g., List et al., 2013, April), and contribute to the literature in terms of the relations between self-perceived competence and epistemic source beliefs.

Studying Context Specificity of Epistemic Cognition

One of the innovations of the current study of epistemic cognition is targeting the context specificity of epistemic cognition. A learning context consists of multiple aspects or dimensions, such as the location, time, medium, teacher, teacher-student interaction, learning topic, and interaction between the learner and the learned (Piaget, 1952). In my dissertation study, I have set out to manipulate one aspect of the learning context—topics of online research—while keeping other aspects controlled, to specify the context, in order to study the role that the context plays in students' epistemic aims and source beliefs. Particularly, I will examine whether or not the epistemic aims set by the students during online research are different based on the three chemistry topics, and whether or not their source beliefs are specific to different topics under research. By studying the context specificity of epistemic aims and source beliefs, I will be able to provide empirical evidence for context specificity of epistemic cognition, in addition to the aspect of domain specificity about epistemic cognition found in prior research (e.g., Muis, Bendixen, & Haerle, 2006).

Developing a Transforming Quantitative Measure of Epistemic Cognition

There have been calls for innovative methodologies for measuring epistemic cognition (Chinn et al., 2011; Hofer & Bendixen, 2012). Compared to the traditional self-report questionnaire, qualitative methods have been found to effectively provide concurrent data about epistemic cognition and contribute to better understanding of epistemic cognition (Ferguson et al., 2012; Strømsø, Bråten, Britt, & Ferguson, 2013). However, it is time-consuming and expensive to apply qualitative methods in large samples, which in turn negatively affects the external validity of research studies. I aimed to develop quantitative questionnaires and embed them in the context of online research on chemistry topics. This design not only retained the advantages of quantitative methods, but also to the largest possible extent tapped epistemic cognition that is proximal to the time when learning occurs in the online research, as well as situating the examination of epistemic cognition in online research on each topic. The new instrument of context-specific epistemic aims and source beliefs moves forward the measurement of epistemic cognition to a more fine-grained, contextualized and yet efficient and economical method.

Relations between Epistemic Cognition and Learning Outcomes in an Internet-Based Learning Context

Chinn et al. (2011) pointed out that the coarse, decontextualized epistemic cognition studied in prior research often failed to predict learning outcomes. Targeting learning patterns and outcomes in a specific context on a specific topic, I aimed to investigate how context-specific epistemic aims and source beliefs may influence learning outcomes in online research on three chemistry topics. Particularly, I sought to understand what types of epistemic aims and source beliefs may enhance learning outcomes in the context of Internet-based research on chemistry topics. The finding of this investigation inform the unique importance of epistemic cognition in learning outcomes in the context of Internet-based learning.

Research Questions and Hypotheses

Based on aims above, I seek to answer the following research questions:

RQ1a. When conducting online research on chemistry topics, do college students set epistemic aims for true beliefs, justified beliefs, and explanatory connection?

I hypothesize that when conducting online research on chemistry topics, college students will set different levels of epistemic aims for true beliefs, for sufficient justification, and for explanatory connections of facts. Based on Chinn et al. (2011) and Chinn, Rinehart, and Buckland (2014), there are various epistemic aims that individuals may set during a learning process.

RQ1b. Are students' epistemic aims specific to the chemistry topic on which they conduct online research?

I hypothesize that the epistemic aims set by students in the online research are specific to different chemistry topics in the online research. Since the different topics are an aspect of the context operationalized in the study, epistemic aims' specificity to topics implies its specificity to contexts. Based on Chinn et al. (2011), Louca et al. (2004), and Bråten et al. (2008), individuals' epistemic aims can be stimulated by and specific to a learning context.

RQ1c. What is the true-score reliability of the subscales on context-specific epistemic aims for true beliefs, justified beliefs, and explanatory connection?

I hypothesize that the reliability of the context-specific measure on context-specific epistemic aims are high: the subscale, *true vs. false beliefs*, has a high internal consistency and subscale true-score reliability; the subscale, *sufficient vs. minimal justification*, has a high internal consistency and subscale true-score reliability; the subscale, *explanatory connections of facts*, also has a high internal consistency and subscale true-score reliability.

RQ2a. Do students evaluate sources based on multiple qualities when conducting online research on chemistry topics?

I hypothesize that when conducting online research on a topic, students do evaluate online sources based on multiple qualities of the sources. Based on Chinn et al. (2011), individuals do not believe *either* only authority *or* only personal experiences; source beliefs are a complex, multidimensional construct.

RQ2b. Do students trust multiple sources in online research?

It is hypothesized that for each chemistry topic college students use multiple sources in online research. Based on Chinn et al. (2011), however trustworthy a source may be conceived, students may seek multiple testimonies.

RQ2c. Do college students trust sources differently to believe versus to refute information presented in the webpage posts?

I hypothesize that students would be more cautious about using a source as support to refute a piece of information presented in the webpage post. If students see a post presenting information that contradicts with a source, students may trust the source less due to the refutation (Sinatra & Broughton, 2011).

RQ2d. Do students trust online sources to different extents for learning different topics?

I hypothesize that students trust the online sources to different extents for learning different topics. Based on Chinn et al. (2011), Louca et al. (2004), and Bråten et al.

(2008), individuals' epistemic beliefs about source can be stimulated by and specific to a learning context.

RQ3. Are epistemic aims and source beliefs associated with learning outcome in the online research on chemistry topics?

I hypothesize that context-specific epistemic aims and source beliefs both have influences on learning outcomes in online research on the three chemistry topics. I hypothesize that these effects of epistemic aims and source beliefs on learning outcomes are above and beyond the effect of prior achievement in an introductory chemistry course and mastery goals, and that the more adaptive the epistemic aims and source beliefs positively predict learning outcomes in the online research on a chemistry topic.

Overview of Chapters

In the following five chapters, I present the theoretical framework, prior research and supporting theories, a pilot study, research design and methodology, study findings, and finding discussion and interpretation of the dissertation study. In Chapter 2, I present a systematic introduction to the theoretical framework of the dissertation study—Chinn et al. (2011)—together with my understandings of applying this framework in the Internet-based learning context, a thorough review of prior research on epistemic cognition in Internet-based learning, and a critical review of the current methodologies of measuring epistemic cognition.

In Chapter 3, I present a pilot study—cognitive pretesting a context-specific measure of epistemic aims and source beliefs—that I conducted prior to this dissertation study, providing evidence for cognitive validity of the newly developed instrument of context-specific epistemic aims and source beliefs. I present the study goals, details of measure development, research methodology, findings, and the methodological and theoretical implications of the research findings.

In Chapter 4, I present a detailed description of research methodology of my dissertation study. I describe the study context, characteristics of participants, study procedure, measures I used to assess epistemic cognition and learning outcomes, and finally data handling and analytic approaches based on research questions. I also provide results of power analysis to estimate the sample size needed to answer the research questions.

In Chapter 5, I present detailed analysis results and research findings based on research questions and hypotheses.

In Chapter 6, I present a synthesis and further interpretation of the research findings based on theories and prior research. I also discuss theoretical, methodological, and educational implications of the dissertation study findings.

CHAPTER 2. LITERATURE REVIEW

There has been little psychological research that explored learning *aims* that are specific for *epistemic* achievements until the theoretical work on the expanded dimensions of epistemic cognition by Chinn and colleagues (Chinn et al., 2011), in which *epistemic aims* were proposed to be a central component of individuals' epistemic cognition. The centrality of epistemic aims in epistemic cognition, therefore, is in need of examination and empirical support. The dimension of *epistemic beliefs about source of knowledge*, however, has been studied since the earliest psychological research on personal epistemology (e.g., Belenky et al., 1986; Hofer & Pintrich, 1997). Yet, most of the research has focused solely on *authority* as the source of knowledge (e.g., Hofer, 2000), which has not revealed how individuals view other sources than authority and how these epistemic beliefs about sources figure into the process of knowing and learning.

The goals of this literature review are (1) to critically review the components—epistemic aims and epistemic beliefs about sources—of Chinn et al.'s framework (2011), (2) to contextualize the study of epistemic aims and beliefs about sources in college students' chemistry learning, and (3) to provide rationale for the purposes and research questions of the dissertation study.

The literature review comprises several sequential sections. First, a brief introduction to psychological research of personal epistemology is provided. Second, I review the conceptual framework of expanded dimensions of epistemic cognition by Chinn and colleagues (Chinn et al., 2011), focusing on the examination of epistemic aims and epistemic beliefs about sources. Third, I discuss the prevalence of Internet use for learning and current challenges in understanding Internet-based learning, and how epistemic cognition plays an important role in this learning context. Finally, I conclude this chapter with a comprehensive review of several widely-applied current measures of personal epistemology to serve as the foundation of measure development for the constructs—epistemic aims and epistemic beliefs about sources.

Introduction to Epistemic Cognition

Psychological studies of *epistemic cognition* (or *personal epistemology*) in the context of education have proliferated in the past decades since the pioneering work on a scheme of intellectual development by William Perry (1970). The psychological research on personal epistemology has focused on (a) how individuals develop, interpret, justify, and evaluate knowledge, and (b) how these subjective conceptions about knowledge and knowing are associated with reasoning, learning processes, and academic achievement (Hofer & Bendixen, 2012).

There have been three main conceptualizations of personal epistemology in education (cf. Buehl & Alexander, 2001; Hofer & Bendixen, 2012; Hofer & Pintrich, 2002). First, epistemological development theories (Baxter Magolda, 1992; Belenky et al., 1986; Patricia M. King & Karen S. Kitchener, 1994; Kuhn, 1991; Perry, 1970) conceptualize personal epistemology as general positions about knowledge that develop from *dualism* (or *absolutism*), *multiplism*, to *relativism*, and *rationalism* (or *evaluativism*). Second, theories of epistemological or epistemic beliefs (Greene et al., 2008; Hofer & Pintrich, 1997; Schommer, 1990) conceptualize personal epistemology as a system of multidimensional beliefs about knowledge and knowing, including beliefs about the structure, sources, and justification of knowledge, which develop in predictable directions along each dimension. Third, the theory of epistemological resources (Elby &

Hammer, 2001; Hammer & Elby, 2002) conceptualizes personal epistemology as context-specific cognitions, rather than stable beliefs about knowledge that individuals hold for all situations. Specifically, the knower has cognitive resources for viewing knowledge as transmitted and for viewing knowledge as constructed. Different contexts trigger the activation of different cognitive resources for the knower to think about knowledge as transmitted or constructed (or both) in a given context (Elby & Hammer, 2010). Although they vary to a great extent, each of the theories of personal epistemology contributes to the understanding of individuals' thinking about knowledge from a unique perspective—some from the standpoint of how individuals develop general understandings about knowledge from adolescence to adulthood, some from the standpoint of beliefs about different domains at a particular developmental phase, and some through a more fine-grained lens of a specific learning context.

In addition to the frameworks that have been widely used in the field of educational psychology, there are several informing theories of personal epistemology applied in the field of science education, including the theory of ways of knowing in the *Psycho-Epistemological Profile* by Royce and colleagues (Royce, 1964, 1978a, 1978b; Smith, Royce, & Ayers, 1967), as well as Lederman's theory on conceptions of the nature of science (Abd-El-Khalick & Lederman, 2000; Lederman, 1992). Royce (1964) analyzed three ways of knowing that are guided by a multi-dimensional, organized system of cognitive processes, and argued that there are three types of psychological processes implicated in knowing. The three ways of knowing include 1) *rationalist*, a way to know by validating views of reality with its logic consistency, which includes rational analysis and conceptualizing, 2) *empiricist*, a way to know by validating views of reality with the reliability and validity of observation, which involves active perception, and 3) *metaphorist*, a way to know by validating views of reality with the universality of insights or awareness, which involves mainly symbolizing (Diamond & Royce, 1980). Each way of knowing depends upon a unique criterion of "truth"—logical vs. illogical for rationalists, perception vs. misperception for empiricists, and universal vs. idiosyncratic for metaphorists (Royce & Smith, 1964). The focus of Royce's (1964) work was on understanding individuals' ways of knowing, which is relevant to the beliefs about process of knowing of Hofer and Pintrich (1997).

Lederman's theory of conceptions of the nature of science, on the other hand, maps onto beliefs about the nature of knowledge with a more specific concern on science. Abd-El-Khalick and Lederman (2000) categorized views about scientific knowledge as (1) tentative, (2) subjective, (3) empirically based, (4) influenced by human inference, imagination, and creativity, and (5) socially and culturally embedded. This theory has been applied in the field of science education to examine both students' and teachers' conceptions of nature of science, and its interplay with science classroom instruction and curriculum development.

Expanded Dimensions Framework of Epistemic Cognition

Based on a variety of research paradigms of personal epistemology as well as the contemporary philosophical studies of epistemology, Chinn and colleagues proposed an innovative conceptual model of personal epistemology—the expanded dimensions framework of epistemic cognition (Chinn et al., 2011). Chinn and colleagues adopted the terminology, *epistemic cognition*, for the target construct—personal epistemology, and defined it as "all kinds of explicit or tacit cognitions related to epistemic or epistemological matters” (p. 141). This model of epistemic cognition includes a number of important dimensions of personal epistemology, e.g., epistemic aims, epistemic value, and epistemic virtue and vices, and provides new perspectives on the widely researched dimensions, e.g., beliefs about structure, sources and justification of knowledge, which accommodates the more comprehensive examination of this highly complex construct and builds the groundwork for disentangling the relations between personal epistemology and other cognitive and motivational constructs in learning, such as academic performance. In addition, Chinn and colleagues (2011) emphasized context specificity of epistemic cognition, and acknowledged the importance of understanding the contextualized (i.e., given a specific learning situation and content to learning, etc.) epistemic thinking.

Model Overview

Considering that a number of highly relevant epistemological topics explored by contemporary philosophers are not featured in psychological and educational research of personal epistemology, Chinn and colleagues (2011) proposed to revisit the literature and expand the dimensions of personal epistemology that have been investigated in the current psychological research (e.g., beliefs about structure, sources, and justification), to include (1) *epistemic aims and epistemic value*, (2) *the structure of knowledge*, (3) *the sources and justification of knowledge*, (4) *epistemic virtues and vices*, and (5) *reliable and unreliable processes of achieving epistemic aims*. Chinn and colleagues argued that by expanding the theoretical framework of personal epistemology to include more philosophically-grounded components, the exploratory and predictive power of epistemic cognition may be improved. Each of the components of this framework is discussed as follows.

Epistemic Aims

Epistemic aims refer to the goals of establishing certain epistemic achievements. Chinn and colleagues (2011) proposed three types of epistemic aims, including true beliefs (vs. false beliefs), sufficiently justified beliefs (vs. minimally justified beliefs), and explanatory connections among items of information (vs. a collection of isolated facts). These aims are related solely to epistemic matters, and the target of the aim setting is achievements of epistemic nature.

Chinn and colleagues (2011) claimed a central position for epistemic aims, due to the conceptual significance of the construct and its potential to increase explanatory and predictive power of epistemic cognition. Epistemic aims "determine whether other cognitions should be classed as epistemic or not" (Chinn et al., 2011, p. 147). Without considering aims, it could be conceptually incorrect to discuss epistemic cognition. Furthermore, epistemic aims help explain learning behavior (Greene & Yu, 2013, April). Because learners often use learning strategies that are inconsistent with their epistemic beliefs, understanding the epistemic aims a learner sets for a specific context and a particular learning task would shed light on the learner's learning approaches and outcomes. Lastly, the type of epistemic aims a learner sets may to a large extent depend on the context where learning takes place. For instance, a learner may aim for true information and seek less justification and less coherence of knowledge if she is preparing for a memorization test on names and terms of presidency of the last 20 U.S. Presidents, but if the same learner is researching for a paper that analyzes the foreign policies of the U.S. government during the Cold War, she may pay less attention to how "true" different historians' theories are, and seek sufficient justification and cohesive information.

Epistemic Value

Chinn and colleagues (2011) argued that individuals set different epistemic aims and commit to different epistemic behaviors because the resulting epistemic achievements have various values to them in a given learning situation. Some people view theoretical knowledge more valuable than the procedural knowledge for writing a theoretical synthesis paper, whereas they deem practical skills more useful than general principles or laws for conducting a science experiment. Therefore, the value one holds for different epistemic achievements is also to a large extent specific to a learning context. The epistemic value is indispensable to epistemic cognition in the sense that it determines together with epistemic aims how individuals would approach a learning task. The measurement of epistemic value is somewhat similar to measuring task importance as in expectancy-value theory, which can be categorized as intrinsic interest value, utility value, and attainment value. However, epistemic value is context-specific and closely related to the epistemic aims an individual set for the specific content to be learned.

Structure of Knowledge and Other Epistemic Achievements

The component, *structure*, in this expanded framework is conceptualized as multi-faceted (Chinn et al., 2011). The *structure* component can be boiled down to: *universal-particular* (denoting views about knowledge being universal or contextual), and *deterministic-stochastic* (referring to beliefs about how stochastic or probabilistic knowledge is). Additionally, this component describes the structure of more fine-grained forms of knowledge, e.g., scientific mechanisms and causal relations, which is more specific than "knowledge" as captured by most epistemic belief theories. For instance, mechanisms of a science domain are defined as the entities and activities organized to explain how a process works or a phenomenon comes about (Machamer, Darden, & Craver, 2000 as cited in Chinn et al., 2011). Learners may be aware and believe that knowledge in chemistry is of high complexity and evolving, but if they do not possess some knowledge about the mechanisms of organic chemistry they would still have difficulty understanding the content on the subject of a chemistry textbook.

Sources and Justification of Knowledge and Other Epistemic Achievements

Source belief is a component of epistemic cognition that is similar to *beliefs about source of knowledge* in prior theories (e.g., Hofer & Pintrich, 1997). In prior research, *beliefs about source of knowledge* has been characterized as such: it is considered epistemologically "naïve" to rely on authority figures (e.g., textbooks, teachers) for knowledge, whereas it is considered epistemologically "sophisticated" to resort to first-hand experiences and personal experimentation for knowledge. This construct has often been operationalized and sometimes conceptualized as a unidimensional factor implying that individuals either learn from authority or personal experiences. Using measures developed based on this simplistic conceptualization may hinder our understanding about how source beliefs may play a role in individual learning.

Chinn and colleagues (2011), however, pointed out that this is often *not* how individuals acquire knowledge. Chinn and colleagues argued that instead of coming from either one type of source or another, knowledge can derive from multiple sources—often times both authority-type sources and first-hand experiences and experimentation.

Correspondingly, two sources of knowledge (e.g., authority-type sources and personal experimentation) should not be considered as two ends of one dimension. They proposed that the source—*authority*—should be conceptualized as *testimony*, a type of sources that are external (vs. by the learner herself) and the learner may evaluate and make judgments about to what extent she believes the testimony supporting her knowledge acquisition. Therefore, using external testimony to acquire knowledge should not be unconditionally classed as epistemologically “naïve”, rather, one should factor in the standards the learner holds for source evaluation and the learning context the learner is in.

This new conceptualization provides at least two dimensions of source beliefs: first, to what extent individuals acquired knowledge from multiple sources, and second, what standards individuals hold for source evaluation. There has been research that examines the different epistemic standards that learners hold for source evaluation (List et al., 2013, April). Research is needed to explore an aspect of source beliefs—to what extent individual learners trust multiple sources for knowledge acquisition.

For the component of justification, Chinn and colleagues proposed a finer-grained examination of justification by not only asking about views toward personal experience as knowledge justification, but also probing thoughts about appropriate evidential standards in a particular situation. These standards are closely related to epistemic values; for instance, people who use testimonial evidence to justify knowledge value testimony.

Reliable and Unreliable Processes for Achieving Epistemic Aims

This component of epistemic cognition taps the causal processes by which people achieve epistemic aims. Specifically, it refers to individuals’ beliefs about reliable vs. unreliable inquiry of knowledge in specific situations. Chinn and colleagues (2011) contended that these beliefs should be examined as one of the central part of epistemic cognition, and they emphasized the importance of the situation specificity of these beliefs. Individuals' thoughts about reliable vs. unreliable inquiry are closely related to the epistemic aims they set for a specific situation. Individuals' beliefs about what is a reliable means of inquiry are likely to be adopted by the individual driven by a specific situation and by a specific epistemic aim.

Epistemic Virtue and Vices

Chinn and colleagues (2011) proposed a component of epistemic cognition that taps a learned, stable disposition—epistemic virtue, which refers to a quality of directing at epistemic aims and being efficacious in achieving such aims. Examples of epistemic virtue include intellectual carefulness and open-mindedness. As opposed to epistemic virtue, epistemic vices refer to lack of epistemic aim orientation and low efficacy of achieving epistemic aims, if any, which therefore "impede rather than facilitate the attainment of knowledge and understanding" (2011, p. 156). Examples of epistemic vices include intellectual cowardice, dogmatism, and closed-mindedness. The researchers also emphasized that although studies on epistemic virtue and vices have treated these cognitions as trait-like dispositions, contextual factors still figure into individuals' epistemic virtue and vices in a specific situation, which raises the need for research effort on the context specificity of epistemic virtue and vices.

Discussion on the Expanded Dimension Framework

Innovations

Epistemic cognition components beyond beliefs. Chinn and colleagues (Chinn et al., 2011) proposed expanding the scope of epistemic cognition in psychological and educational research to include more cognitive-motivational processes, such as epistemic aims, beyond the traditional concerns on beliefs about the sources and justification of knowledge. The purposes of this framework expansion are 1) to capture a more comprehensive and meaningful scope of human cognitions related to knowing, knowledge and other epistemic achievements, and 2) to enhance models of personal epistemology in their power of explaining and predicting learner behavior and learning outcomes. In particular, the inclusion of epistemic aims, as a central component of epistemic cognition, highlights the purpose of knowing the content to learn in terms of three aspects—truth vs. falsity, sufficient vs. minimal justification, and connections and unification of information vs. a list of isolated facts. Arguably, different epistemic aims (e.g., a collection of facts vs. understanding) direct knowledge acquisition differently and lead to different learning outcomes. Understanding the epistemic aims set by individual learners may help explain the process of achieving aims and learning outcomes.

Epistemic aims as a central component of epistemic cognition. Unlike most of the traditionally studied dimensions of personal epistemology (e.g., structure of knowledge, justification), epistemic aims have not been widely discussed as a component of epistemic cognition in psychological research. Chinn and colleagues (2011) contended that epistemic cognition is a network of interrelated cognitions about knowledge and other epistemic achievements. In other words, any cognitive processes that are related to or oriented at epistemic achievements (including knowledge) are of an epistemic nature. Therefore, the newly proposed components, such as epistemic aims, fall in the scope of epistemic cognition, due to the focus of this type of aim setting is specifically on epistemic matters. Suppose a student wants to know whether the information from a blog post about metabolism is correct or not. She is setting an epistemic aim of true beliefs for learning the content of the post. In this case, true beliefs are a type of epistemic achievement, for which the student explicitly or tacitly sets the learning goal.

Epistemic aims of grasping explanatory connections may appear to resemble mastery goals as defined in achievement goal theory, however, Chinn and colleagues (2011) claimed that the construct is not replaceable by mastery goals. Mastery goals refer to an individual's purposes of *developing competence* (Ames, 1992b). These goals orient students to learn, understand, and master, and direct students' attention to whether or not they have mastered knowledge and skills. Researchers have argued that mastery-goals orientation is a purpose of personal development and growth that guides achievement-related behavior and task engagement (Kaplan & Maehr, 2007). Mastery goals are associated with positive motivational and affective outcomes in learning, such as higher self-efficacy, persistence in learning, better self-regulated learning, well-being, and higher school achievement (cf. Kaplan & Maehr, 2007). Epistemic aims, on the other hand, refer to an individual's purpose of "finding things out, understanding them, and forming beliefs" (Chinn et al., 2011, p. 146), and they are set for obtaining an epistemic achievement, which is an achievement of epistemic nature.

Theoretically, epistemic aims of grasping explanatory connections may be differentiated from mastery goals. First, the targets of the goal/aim setting are different between epistemic aims and mastery goals. Mastery goals focus on a long-term view on the development of competence and general achievement over time. The goal setting goes beyond the scope of *episteme* and includes effort utilization and intrinsic value of learning (Ames, 1992b). Epistemic aim setting, on the other hand, is specifically about the content and about achievements related to knowledge. The concern of an epistemic aim is on how items of information connect and fit together (Chinn et al., 2011), rather than about developing competence on the topic by understanding the material.

Second, depending on what kind of epistemic aims a student sets, epistemic aims may or may not orient the student to learn, understand, and master. In other words, the epistemic aims of grasping explanatory connections may not be necessarily associated with mastery goals, but rather performance goals. For instance, if a student sets the epistemic aim of seeking logical connections among items of information in a section of a history textbook, she may be doing so in order to earn a good grade on a quiz in class the next day. In this case the epistemic aim of seeking connection is associated with a performance goal, rather than a mastery goal. Consider another example: A student is mastery-goal oriented in her learning of structural equation modeling, but she lacks basic knowledge in matrix algebra. She therefore decides to memorize that a variance-covariance matrix has the same number of rows and columns (i.e., $n_{\text{row}} = n_{\text{column}}$), rather than connecting $n_{\text{row}} = n_{\text{column}}$ with the definition of square matrices and that a variance-covariance matrix is a square matrix. In this case, the student is setting an epistemic aim of collecting items of knowledge without making further connections, but it does not go against her mastery goal of developing competence in structural equation modeling.

To distinguish epistemic aims of grasping explanatory connections from the mastery goals theorized by motivational researchers, Chinn and colleagues reviewed some instruments of mastery goals and stated that although some items in the mastery goal measures do capture epistemic aims, e.g., “It’s important to me that I thoroughly understand my class work” (Midgley et al., 2000 as cited in Chinn et al. 2011), there are also a great number of items in these measures assessing other aspects of learning rather than the epistemic aspect, e.g., the goal to meet challenges in learning, the goal that focuses on enjoyment of learning, which are not about accomplishing true beliefs, justified beliefs, explanatory connections, or any other epistemic achievements.

The construct, mastery goals, is operationalized so that it captures a broader range of goals that are related to a number of cognitive, motivational, or affective aspects of learning, whereas epistemic aims are specifically about seeking truth, sufficient justification, explanatory connections, or other epistemic achievements, which is a range of goals focus solely on the content to be learned. Therefore, it is unlikely that epistemic aims can be operationalized with measures of mastery goals. The above claims of the differences between mastery goals and epistemic aims are theoretical in nature and lack empirical support. It is therefore one of the research goals of this dissertation study to validate the construct—epistemic aims.

New conceptualization of beliefs about sources. Epistemic beliefs about sources of knowledge are vitally important in knowledge acquisition and accomplishing other epistemic achievements. This dimension of epistemic cognition determines individuals' ability to appreciate different sources in different contexts and to employ sources in learning (Porsch & Bromme, 2011). However, most findings about this dimension have centered only on authority as the source. In studies of epistemological development, researchers have found from interview respondents that individuals who hold dualist views about knowledge tend to think that authority knows the truth about the world and is to convey knowledge to the learner (King & Kitchener, 1994; Kuhn, 1991; Perry, 1970), individuals who hold multiplist beliefs about knowledge tend to believe that authority does not have answers to all questions (Baxter Magolda, 1992; King & Kitchener, 1994; Kuhn, 1991), individuals with relativist views value their own opinions as much as the authority's (Baxter Magolda, 1992), and those who hold rationalist views toward knowledge are capable of critically evaluating evidence and comparing justifications (King & Kitchener, 1994; Kuhn, 1991) rather than blindly believing in authority as the source of knowledge. In research on epistemological or epistemic beliefs, authority as the source of knowledge has been found to be a unique dimension of personal epistemology (e.g., Bendixen & Hartley, 2003; Hofer, 2000; Schommer, 1990; Schraw, Dunkle, & Bendixen, 1995).

Although views about "authority" as a source of knowledge have been found salient in prior research, authority-type sources clearly do not fully represent all sources of knowledge or other epistemic achievements. Focusing only on authority-type sources in research may lead to limited and even misleading conclusions about beliefs about sources of knowledge. For instance, reliance on authority as the source of knowledge has often been found to be related to undesirable learning behavior and outcomes, and yet learning from the experts or experienced others has been one of the most common and necessary ways of acquiring knowledge and skills (Chinn et al., 2011).

As such, Chinn and colleagues (2011) proposed studying a broader range of sources, including perception, introspection, memory, rather than "experience", and reasoning and testimony of others rather than "authority". Particularly for "authority", which often refers to knowledgeable and/or experienced others as a source of knowledge, Chinn and colleagues recommended conceptualizing it as using the source of "testimony" (2011, p. 153), as testimony plays a crucial role in knowledge construction and dissemination, and believing in learning from others should not be deemed as less sophisticated epistemic cognition. Beliefs about sources of knowledge can facilitate or impede learning for individuals at any phases of epistemological development, depending on specific learning situations; therefore, research should focus on the context specificity of believing others' testimony as a source of knowledge.

Emphasis on context-specific cognition. Chinn et al.'s framework of epistemic cognition (2011) emphasized that beliefs may vary across different contexts within a specific domain or discipline, which is consistent with the epistemological resources framework (see Louca et al., 2004 for a review) and the trend of studying "situated cognition" (Seel, 2001, p. 404). In other words, a student might activate certain epistemic cognitions (e.g., setting a certain aim, adopting a certain sets of beliefs) in a context of learning chemistry that are different in another context of learning the same subject matter. The implications for empirical research include (1) more attention should be drawn to the context specificity of personal epistemology, because focusing merely on domain-specific or domain-general epistemic beliefs is not enough for the purpose of understanding learning behaviors, which are situated in various contexts, from the epistemological perspective; (2) the measurement of epistemic cognition should be grounded in specific contexts of learning a disciplinary subject matter; and (3) the generalization should be made within a similar context in the same subject domain. Only by critically comparing and contrasting epistemic cognitions in a variety of contexts of learning a subject matter, should one make inferences about domain-specific beliefs. Obtaining the equivalence between conceptualization and measurement is one of the crucial ways to help guarantee the external validity of research on personal epistemology.

A Graphic Presentation of the Expanded Dimensions of Epistemic Cognition

As previously discussed, the framework of epistemic cognition by Chinn and colleagues (2011) has provided groundwork for expanding the scope of epistemic cognition to include a number of components as well as emphasized the importance of contextualizing these epistemic cognitions in specific learning situations. Based on this framework, epistemic cognition encompasses at least five types of cognitive processes that are related to epistemic matters, including epistemic aims and epistemic value, epistemic virtues and vices, beliefs about the structure of knowledge, beliefs about sources and justification of knowledge, and beliefs about reliable and unreliable processes for achieving epistemic aims.

Clearly, the scope of epistemic cognition in this model extends beyond the traditional scope of "beliefs" as studied in prior research on personal epistemology (e.g., Greene et al., 2008; Hofer & Pintrich, 1997; Schommer, 1990), as it should be due to the high complexity of the construct. It is, therefore, necessary to conceptualize the components of epistemic cognition as different types of cognitive processes. For instance, setting an aim to obtain true information about a topic (i.e., an epistemic aim) in a given learning context is a cognitive process different from evaluating and believing scientific experimentation as a source of true information (i.e., a belief about sources of epistemic achievements), or valuing sufficiently justified arguments more than minimally justified arguments (i.e., an epistemic value). Although all related to epistemic matters, these processes involve different targets, function differently, and serve different purposes in the process of learning, which, as discussed in Chinn et al. (2011), take different measuring methods in order to accurately capture them, and may provide knowledge about different aspects of epistemic cognitions involved in a learning process.

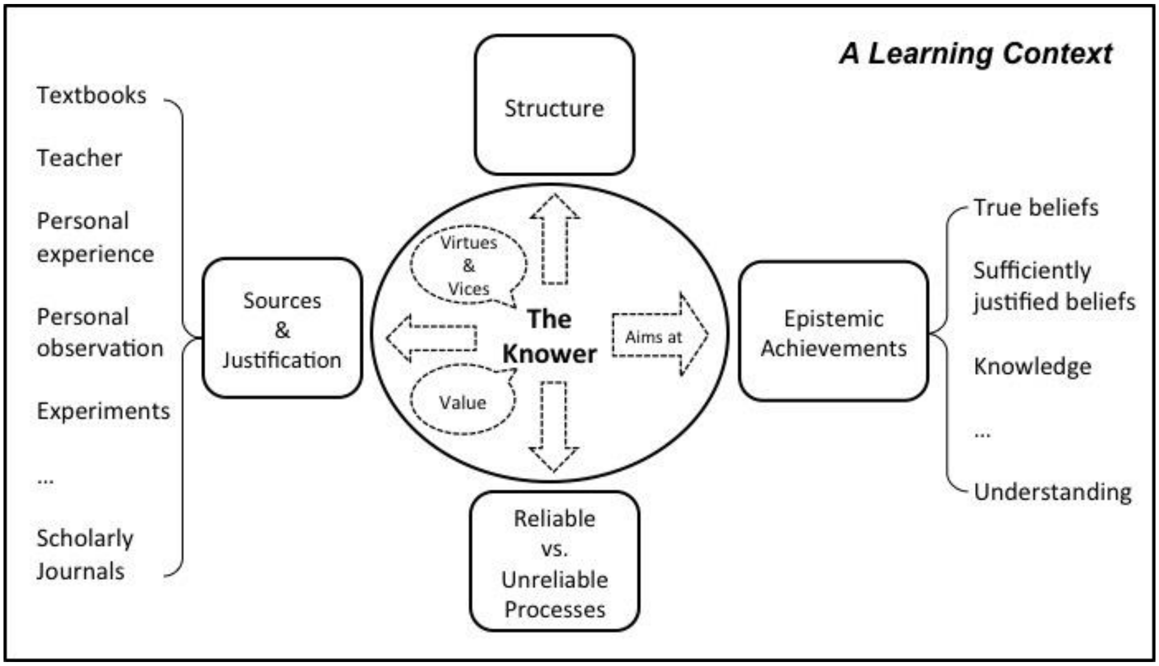

Figure 1. A context-specific model of epistemic cognitions based on Chinn et al. (2011). The arrows represent the knower's thinking processes about epistemic achievements, structure, sources and justification, and reliable vs. unreliable processes that are involved in the process of learning. They do not indicate single-directional inputs.

Figure 1 presents the five different epistemic cognitive processes and dispositions of a learner in a learning context as proposed in Chinn et al. (2011). The diagram emphasizes that it is within a specific learning context that an individual's epistemic cognitions are activated and function in the process of learning. In this context-specific model of epistemic cognitions, a learning context consists of at least two key elements—the content to be learned (e.g., a topic, a skill), and the epistemic resources for learning (e.g., the availability of texts, time allowed, learning media), as suggested by previous research (Wiley et al., 2009). Individuals' epistemic cognitions can be stimulated by the elements of a learning context. The model also presents the targets of the cognitive processes. Epistemic achievements are the potential targets of epistemic aim setting. An individual can set an epistemic aim specific to a given learning context, such as true beliefs, sufficiently justified beliefs, a coherent understanding of concepts, or a combination of the above-mentioned goals. The sources and justification of knowledge are the targets of epistemic evaluation, which is also particular to a learning context. For instance, an individual may value the instruction in an experiment manual more than her own perception and memory when doing a biology experiment for the first time. Similarly, the structure of knowledge and the processes of achieving epistemic aims are targets of epistemic thinking and evaluation[1]. The epistemic cognitions involved in a learning process are to different extents dependent on the specific learning context.

Chinn et al.'s (2011) theory of fine-grained, context-specific epistemic cognition may be applied in a variety of learning contexts to examine the epistemic cognitions involved in the learning process to facilitate the understanding of learning behavior and learning outcome in such context. One of such specific learning contexts can be Internet-based learning of science topics. In the following section of literature review, I present prior research and theories on the prevalence of Internet-based science learning, the challenges for students to learn in Internet-based contexts, and the critical role that epistemic cognition plays in Internet-based learning situations.

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[1] There are also examples of structure of knowledge and reliable vs. unreliable processes of achieving epistemic aims, which are not shown in this diagram of the model. The diagram selectively illustrates the examples of epistemic aims and sources because they are the research foci of this dissertation study.

Epistemic Cognition and Internet-Based Learning

Over the past two decades, the increased access to the Internet and the amount of readily available information online have made the Internet a commonplace source for accessing information. Research has shown that Internet has become the mainstream tool for information for Americans (Horrigan & Rainie, 2002). For today's students the Internet has become a main source of information (Cooper, Cowie, & Jones, 2010). Students are also making increased use of the Internet as a source for solving problems for academic assignments (Mason et al., 2010b). In the process of conducting search, reading sources, communicating, and other related activities online, Internet-based learning may occur. The context of the Internet may also shape individuals' learning behavior and outcomes.

Prevalence of Internet-Based Learning

The Internet has been extensively used for science learning. Approximately 70% of Internet users have utilized the Internet to obtain science news and information (Horrigan, 2006). In a review of empirical studies on Internet-based science learning, Lee and colleagues identified a number of variables pertained to learners' individual characteristics and learning outcomes that are specific to Internet-based learning in the science domains (Lee et al., 2011). The learner characteristics that have been found to play a crucial role in Internet-based learning include demographic variables (e.g., gender and SES), prior domain knowledge, epistemic cognition, metacognitive ability, prior achievement, and Internet-specific self-efficacy. In particular, learners' epistemic cognition about the nature of science and online sources has been found to have an impact on performance in Internet-based science learning. With regard to learning outcomes, Lee and colleagues found generally positive effects of Internet-based learning on students' learning attitudes and motivation, conceptual understanding and conceptual change, general cognitive skills and cognitive skills specific to scientific inquiry (e.g., analytical skills, scientific argumentation, data processing, and epistemic cognition about science). The results of this review on Internet-based science learning imply a critical role of epistemic cognition in this specific learning context, and that investigating epistemic cognition in the context of Internet-based learning may facilitate our understanding of learning on the Internet.

Prior research has found the Internet-based learning context shapes how individuals read online. Internet-based reading and reading competence have been found to be affected by the Internet context (Alexander & Disciplined Reading and Learning Research Laboratory, 2012; Bråten et al., 2011). In their discussion of reading in the information age, Alexander and associates stressed the impacts of new technologies, represented mainly by the Internet, on reading and learning. As a learning context, the Internet features a great amount of information of varied qualities and flexible text presentation formats, which has created a number of challenges for reading and learning on the Internet, due to "the need to deal with, make sense of, and build knowledge from such a variety of sources" (p. 267). Reading and learning on the Internet may be hindered by 1) excessive value placed on accessibility of—rather than quality of—the information online, 2) heavy reliance on the easy task of locating answers with search engines rather than actively constructing knowledge through synthesizing information, 3) lack of ability to evaluate and integrate diverse and often contradictory sources of information, and 4) the high demand of cognitive and motivational resources in Internet-based reading and learning. Alexander and associates stress that a key to successful Internet-based reading and learning is the ability to "respond flexibly and appropriately to the demands of a given text or texts processed for some purpose within a particular time and place" (p. 270). For this reading competence, they emphasized the importance of a few high-leverage meta-strategies, one of which was strategies related to learners' epistemic cognition, which involves specific reflection on the nature of knowledge and knowing and establishing criteria for knowing (Hofer & Sinatra, 2010), and evaluating and validating the knowledge claims in the Internet sources (Richter & Schmid, 2010).

Epistemic Cognition in Internet-Based Learning

In Internet-based searching and learning students are active in epistemic cognition and epistemic metacognition (Mason et al., 2010b; Strømsø & Bråten, 2010). Mason and colleagues (2010b) investigated from the epistemic perspective whether or not university students spontaneously reflect on information found from online searching. They collected think-aloud data during 46 students' online research on potential health hazards of cellphone use, and found that all participants spontaneously expressed epistemic thinking on various dimensions of personal epistemology. Research has also implied that students' epistemic cognitions in online research are specific to the context of the Internet, for the huge variety of knowledge representations on the Internet has led to new ways of knowing—an important aspect of epistemology (Strømsø & Bråten, 2010). In their survey studies, Bråten and Strømsø (Bråten & Strømsø, 2006; Strømsø & Bråten, 2010) consistently found that college students from a variety of majors (e.g., education and physics) reported holding Internet-specific epistemic beliefs in their online research. Students activate their epistemic cognition pertaining to the learning context of the

Internet, which underscores the importance of examining Internet-specific epistemic cognition in order to understand learning behavior and outcomes in such context.

Although students are epistemically active in Internet-based learning, their epistemic cognition may not be adaptive to the context for them to achieve good learning outcomes. Research on Internet-based learning has shown that students are faced with a variety of challenges, in particular, related to epistemic cognition. The Internet has been used as an important source of information (Cooper et al., 2010), despite the varied quality of Internet-based information (Oliveira, Mesquita, & Hermes-Lima, 2010). Even for students who mainly rely on textbooks and teachers, the Internet has gradually come to share the role as a main source in their learning (Clark & Slotta, 2000). However, research has shown that students lack epistemic cognition (e.g., about the nature of knowledge and source evaluation) required to critically select and apply Internet-based information in learning (Priemer & Ploog, 2007; Thompson, Morton, & Storch, 2013; Wang, Ke, Wu, & Hsu, 2012). Particularly in Internet-based science learning, students may not be able to assess and select scientific information from the vast amount of sources available on the Internet, due to unfamiliarity with scientific discourse (Thomm & Bromme, 2012), low scientific literacy (Gardner, Jones, & Ferzli, 2009), and most importantly may lack epistemic cognition required for source evaluation for science learning (Bråten & Strømsø, 2006; Mason, Boldrin, & Ariasi, 2010a; Mason et al., 2010b; L. Mason & Boldrin, 2008).

The different challenges facing Internet-based learners may be related to different aspects of Internet-specific epistemic cognition. Research on epistemic cognition has identified a number of epistemic cognition dimensions specific to Internet-based learning and how they influence learning behavior and outcomes. In the remainder of this section, I will review research that has investigated epistemic cognition in Internet-based learning contexts, with emphases on two dimensions of epistemic cognition—source beliefs and epistemic aims.

Epistemic cognition is of utmost importance in Internet-based learning (Barzilai & Zohar, 2012; L. Mason & Boldrin, 2008; Porsch & Bromme, 2011). Skilled Internet-based learners are better in evaluating the credibility and reliability of sources (Goldman et al., 2012), which implies that adaptive epistemic cognition about sources is essential in Internet-based learning. Research has identified a number of epistemic cognition dimensions that are prevalent in students' Internet-based learning (Chiu et al., 2013; Mason et al., 2010b; Strømsø & Bråten, 2010), including beliefs about the nature of knowledge (or certainty and simplicity of knowledge; Bråten & Strømsø, 2006; Kienhues et al., 2011), beliefs about justification (Bråten et al., 2013; Ferguson et al., 2012), and the most widely-found source beliefs, such as believing either personal experiences or authority-type sources (Goldman, 2011; Halverson et al., 2010; List et al., 2013, April; Madden et al., 2012; Strømsø et al., 2011). These dimensions of epistemic cognition influence students' Internet-based learning in terms of online text comprehension (Bråten et al., 2008; Goldman et al., 2012) and comprehension/integration of information from multiple texts (Bråten et al., 2011), information synthesis (Mason et al., 2010b), problem solving (Goldman, 2011), decision making (Kienhues et al., 2011), reading comprehension strategy use (Barzilai & Zohar, 2012; Bråten & Strømsø, 2006; Bråten et al., 2005), self-regulated learning (Chiu et al., 2013), and Internet-based information evaluation (Kammerer et al., 2013; Wiley et al., 2009).

Source Beliefs in Internet-Based Learning

As prior research indicates, source beliefs are particularly important in students' Internet-based learning. In Internet-based learning, the Internet is both the medium of learning content and the context where learning happens, which demands adequate epistemic cognition about web-based sources, in order to effectively select and obtain reliable information from the Internet (Oliveira et al., 2010; Thomm & Bromme, 2012; Wang et al., 2012). In addition, with the increased availability of online sources of varied qualities, the responsibility of source evaluation falls on the Internet user. Halverson, Siegel, and Freyermuth (2010) found that undergraduate students (N = 127) used a combination of reliable and unreliable sources in their papers on stem-cell research, and held epistemic criteria at different levels for completing independent research reports. They argued that students generally struggled with critical evaluation of online sources and needed specific instruction on how to evaluate and select credible sources from the Internet. Low ability to evaluate sources may demonstrate maladaptive source beliefs in the context of Internet-based learning, and this implies the importance of epistemic cognition about sources.

Source beliefs influencing online source evaluation. Epistemic cognition about sources plays an important role in Internet-based source evaluation. Bråten and colleagues (Bråten et al., 2005) examined the dimensionality of an Internet-specific measure of epistemic beliefs and investigated how these beliefs relate to identification and evaluation of online sources and use of relevant information, with a sample of 157 Norwegian university students in a comparative politics course. The participants completed a group-administered self-reported survey on Internet-specific epistemic beliefs, use of information and communication technology (ICT), Internet self-efficacy, and Internet-based learning activities. Specifically, the Internet-specific epistemic beliefs tapped students' beliefs about the Internet as a source of information relevant to their coursework and the field of study and about evaluating knowledge claims on the Internet. Hierarchical regression results indicated a significant effect of epistemic beliefs about the Internet as a source of information on 1) students' self-reported ability to identify and evaluate Internet sources and 2) ability to use Internet-based information for relevant coursework, above and beyond gender, age, use of ICT, and Internet self-efficacy. Although this study on epistemic cognition was decontextualized from the actual Internet-based learning context, the findings to a large extent indicate the role of student epistemic cognition about Internet source in self-perceived ability to learn with online sources.

In another study on Internet-based source evaluation, Kammerer and colleagues (2013) collected both questionnaire and real-time data (e.g., eye-tracking, log files) of 80 German university non-medical students who conducted a Web search on Bechterew's disease and gave advice on choosing from two therapies to a fictitious friend. The researchers found that the more students believed the Internet to be a reliable source of knowledge the less time they spent on the URLs, the less likely they were to conduct an in-depth search, the fewer verbal reflections they generated on the credibility of the sources, and the more certain they felt about their decision about which therapy to recommend to the fictitious friend. The effects of epistemic source beliefs were estimated with computer search experience as a control variable. The study was contextualized in Internet-based learning, and the learning outcomes were measured both online and offline during an Internet-based search about a specific learning task, rather than simply measuring student-perceived Internet-based learning ability. The findings clearly indicate that Internet-specific epistemic cognition about source is influential in students' online search behavior and source evaluation.

In an experiment study, Wiley and colleagues (2009) studied the effect of direct instruction to improve students' epistemic cognition about Internet-based sources on their performance in choosing and justifying websites as reliable sources for deciding whether a low-carbohydrate diet is healthy. With a sample of 60 undergraduate students from a psychology course, the researchers administered a pretest on knowledge recognition about low carbohydrate diets, a training session on information sources about the topic, and a session in which students evaluate and rank a list of websites based on how reliable each website is as the source of information about low-carbohydrate diets. Of all students in the study, those in the SEEK (source, evidence, explanation, and knowledge) condition read declarative materials on determining source reliability prior to reading through and evaluating websites, whereas those in the control condition only read and evaluated the websites. The template used for website evaluation was the same for students in both conditions. The analysis results showed that students in the SEEK condition (i.e., who received explicit instruction on source evaluation and, hence, held should more adaptive source beliefs) outperformed those in the control condition on posttest knowledge recognition scores, identifying core causes, website ranking discrimination, and frequencies of referring to sources. The findings imply the effectiveness of the SEEK instruction that teaches students about the source of the information, the nature of the presented evidence, the suitability of the evidence for explaining the phenomena, and the fit of the new information with prior knowledge, which facilitates students to develop more adaptive epistemic cognition about source in Internet-based learning.

Source beliefs affecting online text processing. Another aspect of Internet-based learning that source beliefs influence is online text comprehension, integration, and synthesis. Handling and understanding multiple texts has found to be one of the challenges featured in Internet-based reading and learning (Alexander & Disciplined Reading and Learning Research Laboratory, 2012; Bråten et al., 2011). In their study of 135 Norwegian education undergraduates, Bråten, Strømsø and Samuelstuen (2008) examined the effects of beliefs about knowledge simplicity and source beliefs on deep-level understanding of multiple expository texts. They found that students holding "sophisticated" source beliefs performed *poorer* than did students holding "naïve" source beliefs. These findings underscore the importance of source beliefs on reading comprehension. In addition, the results imply that a key to good reading comprehension online is not necessarily "sophisticated" source beliefs but rather source beliefs that are adaptive to the Internet-based reading context. Alexander and associates (2012) pointed out that epistemic cognition is a higher-level process in reading as posited in Kitchener's (1983) framework of cognitive processing, in which epistemic strategies are manifested for comprehension, and that the ability to adaptively employ epistemic strategies is crucial to reading competence in the 21st century contexts. This viewpoint also sheds light on how important epistemic cognition, such as source beliefs, can be to reading in an information-saturated context like the Internet.

Source beliefs affecting SRL online. Epistemic cognition about source has a large impact on Internet-based self-regulated learning and strategy use. Internet-based learning demands abundant cognitive resources from a learner (Alexander & Disciplined Reading and Learning Research Laboratory, 2012), and therefore self-regulated learning skills are essential to Internet-based learning. In their large-scale survey study with 758 Taiwanese undergraduate students, Chiu and colleagues (2013) investigated the relations among four dimensions of Internet-specific epistemic beliefs (i.e. certainty, simplicity, source, and justification) and two aspects of self-regulated learning (SRL) in Internet-based learning (i.e., preparatory SRL and enactment SRL). The researchers confirmed all four factors of epistemic beliefs in their sample, and found that source beliefs had a significant direct effect on preparatory SRL, and an indirect effect on enactment SRL through preparatory SRL. Students who had firmer beliefs that the Internet is a reliable source of information were less likely to set learning goals and adopt appropriate learning strategies for the Internet-based learning task, and hence were less likely to monitor, evaluate, and improve their learning process while searching and learning online. Clearly, maladaptive epistemic cognition about sources negatively affects self-regulated learning in Internet-based learning. Similarly, Goldman and colleagues (2012) also found from their think-aloud study that better readers looked for reliable websites and engaged in more sense-making, self-explanation, and comprehension-monitoring processes on reliable websites than on unreliable websites, and, by comparison, poorer learners engaged in processes like these to a much lesser extent. The differentiation better learners made during Internet-based learning reflects more adaptive epistemic beliefs about sources, and these beliefs are associated with better self-regulated learning on the Internet.

Source beliefs influencing online learning outcome. Lastly, source beliefs play a key role in Internet-based learning outcomes. In their study of students' searching information on whether continuous cellphone use might be a health hazard, Mason and colleagues (2010b) collected concurrent think-aloud data from 46 college students while they were doing Internet-based search for information on the topic. The researchers coded the think-aloud data on four epistemic dimensions, including source of knowledge, and found that source beliefs were most frequently activated while students were doing online search and that students who were higher on source beliefs and beliefs about justification of knowledge performed better in the content recall test compared to those who held lower beliefs on these two dimensions. In a similar study on evaluating and learning from online information, Mason and colleagues (2010a) collected quantitative data on science epistemic beliefs, reading comprehension, online learning approaches, and prior knowledge from a sample of 83 eighth graders in Italy, who conducted a search on the causes of the extinction of dinosaurs. The participants were interviewed in regard to their epistemic cognition specific to the online search task. Internet-specific epistemic cognition about source, in terms of clarity, completeness, agreement with prior knowledge, agreement with course content, and expertise of the sources, was again found most frequently reported in students' retrospective interview. The results also showed that students who held more adaptive Internet-specific source beliefs recalled more content from the search, after controlling for prior knowledge and reading comprehension.

Summary. Given the important role that source beliefs play in Internet-based learning in terms of online source evaluation, reading comprehension, self-regulated learning, and Internet-based learning outcomes, it is crucial to examine students' epistemic cognition about source in order to under learning behavior and outcomes in this specific context. With regard to the mixed findings about source beliefs (e.g., Bråten et al., 2008; Strømsø & Bråten, 2010), it is necessary to 1) differentiate source beliefs from other dimensions of epistemic cognition, and 2) tailor the measurement of source beliefs specifically according to the Internet-based learning context, in order to clarify misconception about this construct and gain in-depth knowledge about how source beliefs affect learning in the Internet context.

Epistemic Aims in Internet-Based Learning

Unlike source beliefs, the dimension of *epistemic aims* has seldom been studied in the context of Internet-based learning. Epistemic aims hold a central position in epistemic cognition (Chinn et al., 2011), but we know very little about how prevalent setting epistemic aims is in Internet-based learning or how these aims, if any, may affect the learning behavior and outcomes in the context of Internet-based learning.

Goals in online reading. Research on aspects of Internet-based learning has tapped the concept of goals or aims. In their review of literature on reading in the 21^{st}-Century context, Alexander and associates (2012) pointed out that reading is goal-directed, which emphasizes the reading goal of the reader, the intentions of the author, and the reciprocal meaning-making process between the author and the reader. We argue that epistemic aims may be categorized as a type of reader goals that are specific to acquiring knowledge and regulating knowing that are involved in reading. Therefore, in the Internet context, epistemic aims would be specific to knowledge and knowing from reading on the Internet. Although Alexander and associates' framework of reading in the

21st Century does not particularly theorize *epistemic* aims in Internet-based learning, the investigation of this construct comes under the umbrella of their theory about reading as a goal-directed behavior. Furthermore, this framework of reading emphasizes epistemic competence, which refers to "epistemic beliefs about knowledge and knowing together with one's ability to suitably adapt to the contextual and intentional dimensions" (Alexander & Disciplined Reading and Learning Research Laboratory, 2012, p.265). Put in the context of Internet-based learning, this notion of epistemic competence highlights that not only need an individual have epistemic beliefs (e.g., source beliefs) about what she reads from the Internet, but her epistemic *beliefs* also need to be adaptive to the specific *context* and her goals including the epistemic *aims*.

Goals in online learning tasks. Researchers have investigated the goal-directed dimension of Internet-based learning. Goldman and colleagues (Goldman et al., 2012) used think-aloud protocols to compare better and poorer learners in terms of the learning approaches they applied and activities they engaged in during an Internet-based learning task. The researchers found that better learners engaged in more goal-directed navigation than poorer learners. In their research on criteria adopted by graduate students when evaluating websites, Madden and associates (Madden et al., 2012), had 48 participants conduct a series of searches on the Internet and think aloud how they were evaluating the websites and what learning processes they were engaged in. The researchers found that the purpose of the search was one of the main influences (in addition to professors' advice and the perceived nature of the website) on how students evaluated the website and how they learned on the Internet. Although their findings showed the importance of goals, aims, or purposes in Internet-based learning, none of this prior research was specifically tapping the epistemic aspect of aims, and therefore was not able to pinpoint what affect *epistemic* aims may have for Internet-based learning.

Studies on goals or aims in online learning. In their study on epistemic beliefs and epistemic strategies, Richter and Schmid (2010) shed light on aims pertaining to knowledge and knowing on the Internet, with a measure of what they called "processing goals" (p.53). Two hundred and eighty-nine university students chose typical texts they would read for their studies and answered questions related to detailed bibliographic information about those texts. They also completed questionnaires on epistemic strategies, attitudes, and processing goals. Specifically, the measure of processing goals tapped the degree to which students pursued a goal of learning factual information and learning about the author's standpoint while reading the chosen text[2]. Findings from path analyses indicated that both the aim of obtaining factual knowledge and the aim of reading the text to learn the author's standpoint predicted knowledge-based validation of the texts: the stronger the factual-knowledge goals were, the less likely students conducted knowledge-based validation; the stronger the standpoint goals were, the more likely students were to conduct knowledge-based validation. In addition, the standpoint goals also positively predicted consistency checking while reading the text. More importantly, these processing goals also mediated the effects of epistemic strategies (e.g., connected knowledge) and prior knowledge on knowledge-based validation during text reading. Although the study was not situated in an Internet-based learning context, it examined learners' goals specifically pertaining to knowledge during an epistemic

[2] A sample item of the subscale on processing goals of factual knowledge reads, "My goal during reading was to keep as many of the facts mentioned in the text as possible." A sample item of the subscale on processing goals of standpoints read, "During reading, I wanted to find out whether I should believe what the text is trying to tell me."

process, and showed the importance of this type of goal in the task of source evaluation and learning from sources.

In a think-aloud study that tapped epistemic cognition and self-regulated learning in an online learning context, Greene and Yu (2013, April) asked 20 participants to think aloud while conducting an timed online search, in addition to completing pre- and post-tests comprising a position essay on whether or not a healthy adult should take a daily vitamin. The researchers used Chinn et al.'s (2011) framework to code the think-aloud transcripts for epistemic cognition, and found three types of epistemic aims held by the participants—information, knowledge, and understanding. The first type of epistemic aim they found was about simply acquiring information without judging whether the information is sufficiently justified. The second type of epistemic aim was wanting to obtain facts that are sufficiently justified. The last type of epistemic aim they found was about obtaining in-depth understanding that is relevant to both prior knowledge and reliable sources about the topic. The researchers also found that although epistemic aims were not related to pre- or post-test performance, they were positively correlated with planning and SRL strategy use, and also related to other epistemic cognitions including justification and source beliefs. The findings from this study imply that students hold certain types of epistemic aims while doing online research on a topic, and that these epistemic aims have influences on self-regulated learning, particularly planning and strategy use.

Source Beliefs and Epistemic Aims in Internet-Based Learning

Among the components of epistemic cognition that Chinn and colleagues (2011) proposed, source beliefs and epistemic aims are arguably the most important for Internet-based learning. Major components of Internet-based learning are 1) to promptly set goals to guide online information searching and 2) to establish criteria for knowledge to accordingly evaluate and validate knowledge claims on the Internet. These tasks involve setting epistemic aims and applying source beliefs. Alexander and associates (2012) in their work on competencies for reading and learning online also emphasize the importance of epistemic cognition and the goal-directed nature of reading and learning in such contexts, which provides further theoretical support for studying individuals' source beliefs and epistemic aims in Internet-based learning. Consistent with theories of epistemic aims and source beliefs in Internet-based learning, a large number of empirical studies have also revealed the roles of these two constructs in learning online. As reviewed in previous sections, source beliefs influence Internet-based information evaluation (e.g., Wiley et al., 2007), online text comprehension, integration, and synthesis (e.g., Bråten et al., 2008), and learning outcomes (e.g., Mason, Boldrin, & Ariasi, 2010). Epistemic aims affect knowledge-based information validation (Richter & Schmid, 2010). Epistemic aims and source beliefs both have been found to have impacts on self-regulated learning in Internet-based learning contexts, especially on planning and epistemic strategy use (Chiu, Liang, & Tsai , 2013; Greene & Yu, 2013). However, little research has been conducted on both of these aspects of epistemic cognition in Internet-based learning to see how these two constructs may manifest in such contexts, how they may interplay with each other, and how they collectively may influence learning outcomes.

In order to study epistemic aims and source beliefs in Internet-based contexts, I needed to employ a measure of epistemic cognition that can properly operationalize the constructs of epistemic aims and source beliefs, as well as focus on the specificity of online learning contexts. In an effort of finding such measure, I reviewed a number of existing measures of personal epistemology and I present the discussion of these measures in the following section.

Measurement of Epistemic Cognition

Overview of Current Measures

The use of self-reported questionnaires to measure epistemic beliefs was initiated as early as Perry's Checklist of Educational Values (CLEV; 1970), and has proliferated since Schommer's (1990) multidimensional epistemological beliefs theory was introduced to the field. There are a number of measures that have been used to understand epistemic beliefs (e.g., Greene, Torney-Purta, & Azevedo, 2010; Hofer, 2000; Royce & Mos, 1980; Schommer, 1990). The questionnaires on epistemic beliefs differ to a large extent in terms of the underlying theoretical frameworks (e.g., the definition of personal epistemology, what counts as epistemic beliefs, how many dimensions are considered in the model), domain-general, domain-specific, or topic-specific, psychometric properties (e.g., construct validity, subscale reliability), and appropriate assessment populations (e.g., grade levels, populations in different cultures). In addition, this research also reveals a number of methodological issues with the current measures (Buehl, 2008; DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008). It is crucial for the present dissertation study to critically compare and contrast these existing measures for the decision on a suitable self-reported instrument of epistemic beliefs that best fits this investigation.

In the remainder of this section, I provide an overview of eight self-reported quantitative questionnaires of epistemic beliefs (or epistemic cognition), which were designed for or have been used with the population of college students, including (1) the Psycho-Epistemological Profile (PEP; Royce & Mos, 1980), (2) the Epistemological Questionnaire (EQ; Schommer, 1990), (3) the Discipline-Focused Epistemological Beliefs Questionnaire (DEBQ; Hofer, 2000), (4) the Epistemological Beliefs Inventory (EBI; Schraw, Bendixen, & Dunkle, 2002), (5) the Internet-Specific Epistemological Questionnaire (ISEQ; Bråten et al., 2005), (6) the Connotative Aspect of Epistemological Beliefs (CAEB; Stahl & Bromme, 2007), (7) the Topic-Specific Epistemic Beliefs Questionnaire (TSEBQ; Bråten et al., 2008), and (8) the Epistemic and Ontological Cognition Questionnaire (EOCQ; Greene et al., 2010), focusing on the aspects of (a) theoretical basis of the measure, (b) dimensionality, (c) level of specificity, and (d) psychometric properties. The subsections on the epistemic beliefs instruments are organized in a chronological order of the publications. The section ends with a critical review of the eight measures and implications for future epistemic cognition measure development.

Royce and Mos's PEP

Theoretical basis. On the theoretical basis of Royce (1964), Royce and Mos developed a self-report measure of beliefs about how knowledge is derived and justified. In accordance with the theory, the measure assess three dimensions of epistemic beliefs—empiricism (viewing the way to obtain knowledge as through direct observation and experimentation; 30 items), rationalism (viewing the way to obtain knowledge as through reason and logic; 30 items), and metaphorism (viewing the way to obtain knowledge as through intuition; 30 items). Assuming different people stress each of the three approaches differently, the purpose of this measure is to provide “a profile of an individual’s epistemological hierarchy” (Smith et al., 1967, p. 529).

Dimensionality. Although Royce and Mos (1980) aimed to describe individuals’ epistemological “hierarchy” using the PEP, they considered the different epistemic styles distinct dimensions. The authors stated that prioritizing one view (e.g., empiricism) does not eliminate the possibility of simultaneously holding a different view (e.g., rationalism) upon how knowledge is achieved, from which one can see—accuracy of the terminology aside—that the PEP measures multidimensional views about ways of knowing. The original theoretical dimensionality of the PEP, as discussed in Smith et al. (1967), was a four-factor structure, including empirical, rational, metaphoric, and authoritarian ways of knowing. However, the authoritarian view was found largely dependent on the other three views, rarely viewed by the respondents as the priority way of knowing, and the subscale shows severely low internal consistency reliability. The subscale, authoritarian view, was then removed from the PEP based on these theoretical and empirical considerations, making empirical, rational, and metaphorical views the three dimensions of the measure. Factor analyses in later works (e.g., Schopflocher & Royce, 1978) also supported the three-factor structure of the PEP.

Level of specificity and psychometrics. The PEP taps domain-general epistemological views. In a note on the development of the measure, Royce and Smith (1964) stated that different people would have different rankings of the three approaches to knowledge, and illustrated this with a possible difference between mathematicians and lawyers in psycho-epistemological hierarchy. The items of the PEP do not specify the subject domain or discipline of epistemology. The test-retest reliabilities of the three subscales ranged from .66 to .87, and the internal consistency was tested and found adequate (Royce & Mos, 1980).

Schommer's EQ

***Theoretical basis*.** Based on Perry's works (1970) on epistemological development, Dweck's research (Dweck & Leggett, 1988) on implicit self-beliefs about intelligence, and Schoenfeld's studies (e.g., 1983) on speed of learning, Schommer (1990) proposed an innovative conceptualization of personal epistemology: rather than only one general epistemological stance at each phase as hypothesized by the epistemological development researchers, the construct is a system of beliefs that consist of five rather independent dimensions: the structure, certainty, and source of knowledge, and the control and speed of knowledge acquisition. She termed these beliefs "epistemological beliefs". The EQ (1990) was based on this conceptualization of personal epistemology, with subscales designed to tap different dimensions of epistemological beliefs.

***Dimensionality*.** Schommer (1990) attempted to validate the conceptualization of the multidimensional epistemological belief system, with a sample of 266 college students (95% freshmen and sophomores) from a junior college and a four-year university (N_{female} = 143). Participants responded to 63 items on epistemological beliefs on a Likert scale of 1 (strongly disagree) to 5 (strongly agree) for each item. Exploratory factor analysis of 12 item parcels successfully extracted 4 of the 5 proposed dimensions, including Innate Ability, meaning ability to learn is innate rather than learned; Quick Learning, meaning learning occurs either instantly or not at all; Simple Knowledge, meaning knowledge is discrete and unambiguous; and Certain Knowledge, meaning knowledge is certain and unchanging. The hypothesized Omniscient Authority (i.e., experts have otherwise inaccessible knowledge) was not extracted from the data. There were no inter-factor correlations reported for the 4-dimension model of epistemological beliefs, thus it is unknown to what extent the four dimensions relate to each other.

Level of specificity and psychometrics. According to Schommer (1990), the EQ did not capture domain specificity of students' epistemic beliefs, but the measure was later adapted into a mathematics-focused version to measure mathematic-domain-specific epistemological beliefs (Schommer-Aikins, 2008; Schommer, Crouse, & Rhodes, 1992). The descriptive titles of the four dimensions were named based on the corresponding item subsets of .50 or higher factor loadings. However, there were no item-level findings or subscale-level reliability reported for the EQ in Schommer (1990).

Hofer's DEBQ

Theoretical basis. Hofer (2000) developed a discipline-focused questionnaire based on the conceptualization of epistemic beliefs in two areas—the nature of knowledge and the nature of knowing (Hofer & Pintrich, 1997). In beliefs about the nature of knowledge, there are two dimensions—Simple Knowledge and Certain Knowledge, and in beliefs about the processing of knowing, there are also two dimensions—Justification for Knowing and Source of Knowledge. The four dimensions of epistemic beliefs were conceptualized as four facets of personal epistemology, and they are hypothesized to be generally independent of, yet moderately related to, each other.

Dimensionality. The DEBQ consisted of 27 items, which were adapted from and constructed based on Perry's Checklist of Educational Values (1970) and Schommer's EQ (1990). Each item referred to the domain or discipline as the reference frame. A 5-point Likert scale was used for the responses to the items (from "strongly disagree" to "strongly agree"). A total of 326 college freshmen (N_{female} = 172) completed a packet of instruments including a DEBQ on Psychology epistemological beliefs and one on Science epistemological beliefs. Results of the exploratory factor analyses of the psychology- and science-belief items suggested a four-factor model for each. These dimensions are Certain/Simple Knowledge, Justification for Knowing-Personal, Source of Knowledge-Authority, and Attainability of Truth, which represented a narrower conceptualization of epistemological beliefs than Hofer and Pintrich's (1997) framework. First of all, Certainty and Simplicity did not emerge as separate dimensions, and Hofer speculated that the two dimensions of beliefs operated as one despite the different theoretical meanings. Second, the retained items of Justification for Knowing denoted the view that knowing is justified by individual opinion or firsthand experiences, but not representing knowing justified with existing models or secondhand experiences. Third, the retained items of Source of Knowledge, on the other hand, entailed that knowledge originates from expert knowledge, textbooks, and external authority but not self-construction of knowledge. In addition to the theorized dimensions, there was an unhypothesized dimension extracted from the measure, Attainability of Truth, composed by only two items. The inter-factor correlations[3] ranged from -.33 to .54, which indicated

[3] The negative correlation was between the dimensions of Justification-Personal and Source-Authority. However, these two subscales were still found as two separate dimensions of epistemological beliefs. They are not to be mistaken for two opposite poles of one dimension.

that the four dimensions of epistemic beliefs measured by this measure were independent yet correlated to a moderate extent.

Level of specificity and psychometrics. Hofer (2000) further tested the domain specificity of the DEBQs by comparing the mean scores of the psychology-focused and the science-focused questionnaire data. Dependent-sample *t* tests showed significantly different dimension subscale scores between psychology and science, which supported the hypothesis of domain specificity. The internal consistency of the measures was not reported, but the retained items of the two measures all showed acceptable loadings on the corresponding factors (i.e., above .40 except for one Source-Authority item that loaded .32 on the Psychology questionnaire).

Schraw et al.'s EBI

Theoretical basis. Following Schommer's five-dimension conceptual framework, Schraw and colleagues (2002) intended to construct a shorter, more reliable instrument that assesses all five dimensions of epistemic beliefs proposed by Schommer (1990). They pointed out that a plausible reason for previous failed attempts (e.g., Schommer, 1990; Schommer et al., 1992) in finding the hypothesized dimension, Omniscient Authority, was due to parceling items prior to analysis and using item parcels for the measurement model, which affected empirical factor solutions. The EBI, therefore, can be deemed as a reevaluation and modification of the theoretical framework and the EQ by Schommer (1990).

Dimensionality. One hundred sixty undergraduate students ($N_{\text{female}} = 104$), mainly sophomores and juniors, responded to the 28 items of the EBI, which were constructed based on the five dimensions of Schommer (1990), including 7 original items from the

EQ. Each item was reported written to adapt to the level of college students and on a Likert scale of 5 (from “strongly disagree” to “strongly agree”). The authors also obtained retest data of the EBI from the same participants one month later (rate of response = 77.5%) for replication of the analyses. Exploratory factor analysis with the item-level EBI data extracted five factors—Omniscient Authority, Certain Knowledge, Simple Knowledge, Quick Learning, and Innate Ability, which confirmed the five-dimension factor structure proposed by Schommer (1990). The inter-factor correlations among the five factors were relatively low with five of them nonsignificant, which suggested that the five dimensions of epistemic beliefs yielded by the EBI data were rather independent and correlated to each other at a very low level. The re-test data generated a similar factor structure with minor item loading inconsistencies.

Level of specificity and psychometrics. Due to the fact that the EBI was constructed based on the EQ (Schommer, 1990), which is a domain-general measure of epistemic beliefs, the EBI also assessed domain-general epistemic beliefs. Out of the original 28 items, 15 items were retained based upon a factor loading cutoff of .3, with 3 items loaded on each factor. The internal consistency of the subscales ranged from .58 to .68 for the EBI.

Bråten et al.’s ISEQ

Theoretical basis. Bråten and colleagues (2005) constructed an Internet-Specific Epistemological Questionnaire (ISEQ) based on the multidimensional framework of epistemological beliefs by Hofer and Pintrich (1997), and the suggestion by Hartley and Bendixen (2003) that there is a greater influence of epistemological beliefs on learning in new technology environments. The authors considered students’ greater control over learning and sources in the new technology environment (e.g., the Internet) than in a traditional learning setting, and aimed to take into account the features of such a learning environment when assessing student epistemological beliefs and examining how these Internet-specific beliefs influence learning in the context of Internet.

Dimensionality. A total of 36 items were written to assess the four dimensions proposed by Hofer and Pintrich (1997)—simplicity, certainty, source, and justification of Internet-based knowledge. In the examination of the factor structure, 8 items were eliminated from further analyses due to low correlations with other items. A maximum likelihood exploratory factor analysis with oblique rotation indicated a 2-factor structure of the remaining 28 items. Another elimination was done on items that had low factor loadings. The EFA on the remaining items indicated a 2-factor structure, which were labeled General Internet Epistemology (14 items) and Justification for Knowing (4 items). A follow-up CFA with the 2-factor structure fit the data adequately. The factor analyses results seemed to indicate that beliefs about simplicity, certainty, and source are not distinguishable from each other, and that justification manifests itself as an independent dimension of Internet epistemological beliefs.

Level of specificity and psychometrics. The context focus of the ISEQ is on the Internet. The items in the general knowledge subscale specify that truth, correct answers, information, facts, sources, and so on are located on the Internet. The items in the justification subscale tap views about knowledge claims and arguments that are encountered on the Internet. The specificity level of the measure is bound to course content and course work, which are not restricted to only one course. Therefore, the measure was not developed to be a domain-specific epistemology measure, because there was not a particular domain or subject matter specified in the items; rather, the specified aspect is the learning context—the Internet. In this sense, the ISEQ is unique in its specificity regarding the source or media of the content to learn, unlike the other measures of personal epistemology specifying the subject domain or discipline of the content to learn.

The final version of the ISEB in Bråten et al. (2005) comprised 2 subscales—General Internet Epistemology (14 items) and Justification (4 items). The subscale reliability index was a Cronbach's alpha of .9 and .7, respectively, and item loadings ranged from .42 to .73.

Stahl and Bromme's CAEB

Theoretical basis. Stahl and Bromme (2007) pointed out a variety of issues in conceptualization and measurement in the research of personal epistemology, and proposed an set of structural assumptions about the architecture of epistemological beliefs—the *denotative* and *connotative* aspects of epistemological beliefs, which they deemed as helpful for obtaining a deeper understanding of the existing conceptual and methodological issues surrounding epistemological beliefs. The denotative aspect refers to explicit, functional meanings and ideas about knowledge and knowing, and the connotative aspect refers to the evaluative, associative assumptions about the nature of knowledge and knowing. Breaking down the two aspects of epistemic beliefs leads to a possible explanation for measurement problems with prior instruments, which is that the researchers might intend to measure the denotative ideas with their questionnaires, whereas the students might use the evaluative-associative judgments to guide their responses to the items. By designing epistemic belief instruments to focus on either the denotative or the connotative aspects, measurement inconsistency might be prevented. Therefore, Stahl and Bromme (2007) developed the Connotative Aspects of Epistemological Beliefs measure as a supplement to the other instruments that aimed to focus on and efficiently measure the connotative aspects of beliefs.

Dimensionality. The CAEB was developed by comparing a few existing measures, including the EQ (1990) and the DEBQ (2000), and selecting from these instruments three dimensions: beliefs about 1) Simplicity of knowledge, 2) Certainty of Knowledge, and 3) Source of Knowledge. The researchers then chose 24 pairs of widely used adjectives from the literatures on epistemic beliefs to describe the three dimensions of epistemic beliefs, eight pairs for each dimension. Each pair was designed to be the two opposites of a connotative aspect of epistemic beliefs (e.g., definite vs. ambiguous, refutable vs. irrefutable), and respondents were to rate agreement regarding the connotative aspect on a 7-point scale.

A total of 634 college students (N_{female} = 411) from six different universities attending a biology course responded to three domain-specific versions of CAEB. Exploratory factor analyses indicated a 3-factor solution for the structure, but consistently in the three EFA models, the subscale on Source of Knowledge showed low internal consistency. Therefore, the researchers excluded this subscale from the final version, obtaining a 2-factor 17-item CAEB. Since the items loaded on the two factors differently from the hypothesized assignment, the researchers relabeled the two factors to be Texture rather than Simplicity, and Variability instead of Certainty. The inter-factor correlations were all negative, ranging from -.27 to -.40, consistently for the three domain-specific EFA models. The study was replicated with another group of college students in an organic chemistry course who responded to the CAEB measures. Confirmatory factor analyses showed that the two-factor structure was supported, but mean comparisons only partially confirmed the domain specificity (i.e., the scores of the subscale, Variability, were nonsignificantly different for between the three domains).

Level of specificity and psychometrics. Based on the low to medium correlations between the factors in the three domains and the different domain-level sum scores between the three domains, Stahl and Bromme (2007) concluded that students' beliefs were domain-specific as measured by the CAEB. The retained subscales—Texture and Variability—showed acceptable internal consistency (i.e., Cronbach's α = .77 ~ .84).

Bråten et al.'s TSEBQ

Theoretical basis. Bråten, Strømsø, and Samuelstuen (2008) constructed a topic-specific measure of epistemic beliefs, which taps undergraduate students' beliefs about climate change. The measure was based on Hofer and Pintrich's (1997) theoretical model of multidimensional epistemological beliefs, which includes the epistemic dimensions of simplicity, certainty, source and justification of knowledge, as well as Muis and colleagues' (2006) Theory of Integrated Domains in Epistemology (TIDE) framework, in which the notion of topic-specific epistemic beliefs was theorized as a more fine-grained level of personal epistemology in addition to the domain-general and domain-specific levels of epistemic beliefs.

Dimensionality. The 49 items were written primarily to assess the four dimensions as in Hofer and Pintrich (1997). The factor structure of the topic-specific measure was quite consistently supported by empirical data from samples of undergraduate students, who in the studies read multiple texts on climate change and were tested how well they comprehended the texts (Bråten et al., 2008; Strømsø, Bråten, & Samuelstuen, 2008). Of the four dimensions, source and simplicity were positively correlated, and justification for knowing was also positively correlated with certainty and source of knowledge, which was consistent with findings from prior research (e.g., Hofer, 2000).

Level of specificity and psychometrics. With acceptance of the domain-general and domain-specific levels of specificity for epistemic beliefs, Bråten and colleagues (2008), however, focused on a more finer-grained level of epistemic beliefs—topic-specific beliefs, in order to understand whether students' epistemic beliefs are specific to a given topic within a domain. They chose climate change to be the topic of the texts and accordingly assessed students' epistemic beliefs about climate change along the four dimensions—simplicity, certainty, source, and justification.

There were 49 items written to assess epistemic beliefs specific to climate change, but the retained items for each dimension differed from study to study. Bråten and colleagues identified six items for the dimension, certainty, six for simplicity, five for source, and seven for justification, and subscale-level internal consistency ranged from .54 to .72, with simplicity having the lowest subscale reliability. The factor structure has been confirmed with CFA in multiple studies with multiple samples, which supports the construct validity of topic-specific epistemic beliefs.

Greene et al.'s EOCQ

Theoretical basis. The EOCQ measure (Greene et al., 2010) was constructed based on the theoretical model of epistemic and ontological cognition development

(Greene et al., 2008), which specifies relations between the development positions and dimensional aspects of beliefs about knowledge and knowing.

The EOCD model attempted to make a distinction between individuals' ontological and epistemic cognition. Greene and colleagues agreed with the term "epistemic cognition" proposed by Kitchener (R. F. Kitchener, 2002), rather than "epistemological beliefs" or "epistemic beliefs", to emphasize *thinking* about knowledge and knowing. Nonetheless, they argued that epistemic cognition represents only beliefs about the nature of knowing, whereas beliefs about the nature of knowledge should be categorized as ontological cognition rather than epistemic cognition. Accordingly, Greene and colleagues proposed that ontological cognition included the dimension, Simple and Certain Knowledge, and under epistemic cognition there were two dimensions—Justification by Authority and Personal Justification. Studies of beliefs about knowledge and knowing should focus on individuals' ontological and epistemic cognition.

Dimensionality. Greene and colleagues (Greene et al., 2010) developed two domain-specific versions of the EOCQ, one in math and the other in history. Each measure consisted of 13 items, all on a Likert scale of 6 (from "completely disagree" to "completely agree"). The dimension, Simple and Certain Knowledge, was measured by five items; Justification by Authority and Personal Justification each was assessed by four items. The self-reported EOCQ data were collected from 740 participants from middle school (n = 127), high school (n = 173), undergraduate (n = 305), and graduate students (n = 135). Confirmatory factor analysis results supported the three-dimension factor structure of both EOCQs—math and history. Within each domain CFA model, the inter-factor correlations indicated significant negative relations of Personal Justification with the other two dimensions, and this finding was consistent across the two domains.

Level of specificity and psychometrics. The domain specificity hypothesis was also supported by the comparisons of the domain-general models and the domain-specific ones. The domain-specific model fit the data better than the domain-general mode, suggesting that the epistemic and ontological cognition measured by the EOCQs were related to and differentiated between the two assessed subject domains. In regard to the domain subscale reliability, all subscales of both math and history EOCQs had acceptable Coefficient *H* (i.e., above .7; Hancock & Mueller, 2001), except for Simple and Certain Knowledge in math (*H* = .451). In general, the two domains-specific versions of EOCQ displayed acceptable subscale reliability.

Discussion of Current Measures

Scope of Epistemic Cognition

Most of the current measures of personal epistemology adopt the theoretical framework of multidimensional epistemic beliefs. The measures intend to operationalize a number of dimensions, including beliefs about the nature, source, and justification of knowledge, and the ways of knowing. Among these theoretical dimensions, simplicity and certainty of knowledge (or the combined dimension of the two), are the most commonly proposed and found in the empirical testing of dimensionality (i.e., in 6 out of 8 measures and their validation; e.g., Greene et al., 2010; Hofer, 2000; Schommer, 1990; Stahl & Bromme, 2007). None of the measures have operationalized the theoretical dimension, epistemic aims (Chinn et al., 2011), which leads to limited knowledge about one of the central components of personal epistemology. The need for empirical support for the expanded dimensions of epistemic cognition calls for new scale development to realize a proper and comprehensive measurement and validation of the construct.

Measurement of Source Beliefs

Among the dimensions that are assessed in the current measures, source of knowledge has not been consistently operationalized (Schommer, 1990; Schommer et al., 1992; Stahl & Bromme, 2007). When this dimension of epistemic beliefs is successfully assessed with some of the measures, it is either not distinguished from other dimensions (Bråten et al., 2005), or only partially operationalized (e.g., only the beliefs about authority as the source are captured by the measures; Hofer, 2000; Schraw et al., 2002). These findings may lead to problematic interpretations of the dimension and misunderstandings about one of the sources—"authority", as it is most often termed. First of all, it may cause the misunderstanding that authority is the only source of knowledge. Source-Authority, a subscale that only partially operationalizes the source dimension, does not assess any beliefs about the non-authority sources. Related findings may therefore over-represent beliefs about authority as the source of knowledge. Second, when Source-Authority beliefs and a partially operationalized justification dimension—Justification-Personal beliefs—are both found in a study of epistemic beliefs (e.g., Hofer, 2000), the two dimensions can be easily mistaken as the opposites of one dimension, which leads to misunderstanding about the multidimensionality of personal epistemology. Correspondently, it may lead to the misconception that it is epistemologically naïve to acquire knowledge from "authority" and epistemologically sophisticated to justify knowledge with personal experiences and experimentation. Assessment and theories that are based on this conceptualization may distort understandings about personal epistemology.

It is crucial to correct these misinterpretations about source of knowledge by clarifying the conceptualization and improving its measurement. Chinn and colleagues (2011) emphasized the notion of multiple sources of knowledge, and proposed to use the term “testimony” (p. 153) instead of “authority” to represent external sources (as oppose to personal perceptions, experiences, memories, etc.). The rationale for this proposal is that when individuals think about whether or not an external source is trustworthy enough to be a source of knowledge, the main object of consideration and evaluation is the strength of testimony of this source. In other words, beliefs about external sources concern *whether* and *why* a testimony is trustworthy to an individual. Originating from an “authority” may be evaluated by some individuals as a solid condition for a source of knowledge, but, generally speaking, it is not the necessary and sufficient criterion under all circumstances. Therefore, in the measurement of beliefs about sources of knowledge, it is important to not only examine beliefs about multiple different sources (personal and external), but also probe the consideration and evaluation of testimony from external sources, in order to avoid oversimplifying individuals’ beliefs about source of knowledge in empirical studies and theory development.

Levels of Specificity

Most of the current measures of epistemic beliefs are either domain general (Schommer, 1990; Schraw et al., 2002) or domain specific (Greene et al., 2010; Hofer, 2000; Stahl & Bromme, 2007). Both the domain-general and domain-specific foci are on strong theoretical bases (Buehl & Alexander, 2002; Hofer & Pintrich, 1997; Muis et al., 2006; Palmer & Marra, 2008). Muis and colleagues (2006) provided a careful review of the 19 empirical studies on personal epistemology, including between-subject and within-subject designs, to discuss the generality and specificity of epistemic beliefs. The authors proposed a theory of integrated domains in epistemology (TIDE), which shows that individuals' academic epistemic beliefs have both domain-general and domain-specific components. The TIDE framework clearly defines "general epistemic beliefs" (p. 33) as those that develop in informal educational contexts, "academic epistemic beliefs" (p. 35) as those that develop continuously as individuals begin formal education in an educational system, and "domain-specific epistemic beliefs" (p. 36) as beliefs related particularly to a domain and developed as individuals are exposed to the domain. Based on the TIDE framework, the previously discussed measures assess different levels of specificity of individuals' epistemic beliefs—the domain general measures tend to capture variations of general and academic epistemic beliefs, and the domain-specific ones are likely to assess specific epistemic beliefs about a domain of interest.

The different levels of contexts are emphasized in the TIDE framework (Muis et al., 2006) as the environments, in which epistemic beliefs of different levels of specificity are constructed and bound. The role of the learning context in triggering and developing epistemic cognition is also discussed in recent theoretical works. Chinn and colleagues (2011) proposed situational epistemic cognition in their expanded dimension framework, which is a more specific epistemic cognition than domain-general and domain-specific. They argued that individual learners could have completely different epistemic ideas about topics within the same subject domain, depending on different learning contexts. This notion of context-specific epistemic cognition emphasizes the instantaneous thinking about knowledge and knowing about a topic within a specific learning context, which is even more fine-grained than the development of domain-specific epistemic beliefs influenced by an "instructional context" (p. 30).

Amongst the current epistemic belief measures, the ISEQ (Bråten et al., 2005) and the TSEBQ (Bråten et al., 2008) are designed to measure epistemic beliefs at a more fine-grained level than domain-general or domain specific. The former considers the factor of learning contexts and specifies to measure epistemology about the Internet, and the latter considers the uniqueness of a topic within a domain and assesses epistemic beliefs particular to the content on a given topic. However, the two measures may still not capture the subtle epistemic cognition triggered by a specific topic in a learning context, as proposed by Chinn and colleagues (2011). The items on the ISEQ are focused on views upon information obtained from the Internet that is related to a course, rather than knowledge about a topic in a discipline. The TSEBQ, on the other hand, measures beliefs about a particular topic, but fails to account for the learning context in which an individual learns. To understand individual learners' situational epistemic cognition, a measure needs to be tailored to specific contextual conditions and specify knowledge about a specific topic.

Psychometric Properties

There is some support for reliability and validity of the existing measures of personal epistemology. Cronbach's alpha is the most frequently provided evidence for internal consistency of subscales of these multidimensional measures (i.e., used in 4 out of the 6 studies that reported internal consistency). However, test-retest reliability was reported for only one of the measures. The main issue that calls for attention is that the subscales with inadequate reliability have often been put in use without improvement, and this may lead to difficulty in interpreting the epistemic beliefs data and even misinterpretations of the findings. Another issue with the reliability of the current measures is that most of the measures do not report multiple types of reliability (e.g., both test-retest reliability and internal consistency) to demonstrate a more comprehensive picture of the measure's reliability.

Studies using the current measures widely test using exploratory or confirmatory factor analysis and report item loadings and inter-factor correlations, which to some extent demonstrates evidence for construct validity. However, there has not been research attempting to specifically support discriminant and convergent validity for the dimensions of personal epistemology, which are key for the validation of a multidimensional construct (Lance, Baranik, Lau, & Scharlau, 2009). The limited support for validity in measures development and the lack of measurement improvements in the face of low reliability both hinder the proper operationalization of the construct—multidimensional personal epistemology, which calls for a detailed examination of construct (discriminant and convergent) validity for future epistemic cognition measure development.

Measuring Fine-Grained, Context-Specific Epistemic Cognitions

Chinn and colleagues (2011) proposed appropriate methodologies for research on the five components of epistemic cognition in their expanded dimensions framework. In general, the five proposed aspects of epistemic cognition are likely to be too broad to be covered by one survey questionnaire or interview protocol. It is a multiple-phase, multiple-study effort to fully understand epistemic cognition at a fine-grained, context-specific level. They recommended researchers design several studies, each of which focuses on “a subset of relevant [epistemic] cognitions” (p. 163), and synthesize the findings of the studies for a comprehensive picture of epistemic cognition. In order to capture the nuances of these contextualized epistemic cognitions, the measures need to be tailored for different learning contexts and topics to reflect environmental variations. For instance, context-specific questionnaires can be useful for obtaining information about epistemic aim adoption (e.g., simulating or describing an actual learning context in the instructions for completing the measure). The researchers also called for measuring more fine-grained beliefs for explicit and tacit beliefs about different sources of knowledge as well as attention to situational variations of this aspect of epistemic cognition.

CHAPTER 3. PILOT STUDY

Overview

Using the framework of epistemic cognition by Chinn and colleagues (2011), I developed an initial version of the context-specific epistemic aims and source beliefs questionnaire (CEASBQ). I piloted the CEASBQ with college students in order to gain a better understanding of these students' epistemic cognition, to test the cognitive validity of the construct, and how the measure may be further improved in validity and reliability. I examined the students' interpretations of the items for consistency with my assumptions and intended meanings of the specific constructs—epistemic aims and source beliefs—which the items are designed to measure. My approach to examining the cognitive validity was cognitive pretesting (Karabenick et al., 2007), which provided insights on the cognitive processing that occurred when participants were responding to the CEASBQ.

Study Goals and Research Questions

The study employed cognitive interviewing to achieve two goals. First, I aimed to pilot the newly developed CEASBQ, in terms of the comprehensibility of the items, appropriateness of the response scale, the length of the questionnaire, and so on, in order to improve the validity and reliability of the measure. Second, I sought to understand college students' epistemic aims and epistemic beliefs about sources of knowledge in online research on three chemistry topics.

The research questions concerned students doing online research on three chemistry topics—*the danger of antifreeze*, *heartburn*, and *corrosion of iron*:

1. How do college students interpret the draft CEASBQ?

2. What epistemic aims, if any, do college students set for learning in online research?
3. Do college students believe in multiple sources of knowledge? If so, how do they evaluate different sources of knowledge?
4. Do college students' epistemic aims and source beliefs differ in the online research on the three topics?

Method

Design

There have been two practices of cognitive pretesting that are widely used for improving questionnaires—think-aloud and verbal probing protocols (Willis, 2005). In a think-aloud protocol, the interviewer administers the session and prompts the participant as necessary to ensure the participant reads aloud and verbalizes what he or she is thinking during the process of completing the questionnaire. The prompts typically exclude pronouns such as "me" and "us" to ensure minimal social interaction between the interviewer and the participant involved in the process. According to Ericsson and Simon (1993), participants' self-report based on a think-aloud protocol is non-reactive, veridical output from short-term memory.

An alternative to the think-aloud protocol is the verbal probing protocol, including concurrent and retrospective verbal probing, in which the interviewer asks the targeted questions and the participant answers them one by one. With a *concurrent* verbal probing protocol, the interviewer probes further explanation and elaboration of a given answer and the relevant information immediately after the participant has answered each question. With a *retrospective* verbal probing protocol, the interviewer probes further explanation and elaboration after the participant has responded to all items on a measure (Willis, 2005). As opposed to the think-aloud protocol, a verbal probing protocol is structured and involves social interaction, and the participant's report is reactive.

The design of the current cognitive pretesting study was a combination of the concurrent think-aloud and the retrospective verbal probing method with both prewritten and emergent probes after the participant completed the questionnaire. Although thinking aloud affects responses to the questionnaire, this influence is minimal (Ericsson & Simon, 1993), so that the responses to the items to a large extent reflect the participant's actual epistemic cognition. The self-report in a think-aloud protocol is free from bias imposed by the interviewer (Willis, 2005), which ensures to a greater degree the validity of the verbal data, compared to those from concurrent verbal probing. The think-aloud protocol, however, also has a number of disadvantages, including dependence on participant think-aloud proficiency, burden on the participant, and the possibility of completely irrelevant self-report, which makes a structured protocol necessary to supplement the think-aloud. In verbal probing, the interviewer maintains control of the interview, which ensures the relevance of the participant's report. The interviewer is also able to center the investigative focus, which, if used as a supplemental tool to the think-aloud, would enable the interviewer to direct the participant to elaborate on unclear parts in the think-aloud and further explain points of interest emergent in the think-aloud. Combining the two practices in the cognitive pretesting is recommended by Willis (2005), in which he explains that the two methods actually fit seamlessly together, and that using them to supplement each other makes a flexible approach to pretesting questionnaires.

Participants

Participants were students in an urban university in the mid-Atlantic region of the US who enrolled in an introductory chemistry course required for STEM majors—General Chemistry I (CHEM 1031)—in Summer Session I of 2013. A total of 10 college students consented and participated in the study. The students participated in the study on a voluntary basis. The students received a gift card for $50 for their participation in the study. None of the participants were younger than 18 at the time of participation (*M* = 19.2, *SD* = 2.6; see Table 1 for other demographic information). Participants predominantly spoke English as their first language. The sample was diverse in years in college, majors, race, sex, parents' education, and this diversity was representative of students in the summer session of the course.

Table 1

Pilot Study Participant Demographic Information

Demographic Variable	*M*	*SD*
Age	23.7	4.8
	n	%
Ethnicity		
Asian	1	10%
Black	1	10%
Hispanic/Latino	3	30%
White	3	30%
Mixed	2	2%

Table 1, continued

Demographic Variable	*M*	*SD*
First Language English	8	80%
Parent’s Highest Educational Attainment		
Graduated from HS	1	10%
Some college/Community college	2	20%
Bachelor's	1	10%
Graduate degree	6	60%
Year		
Sophomore	3	30%
Senior	2	20%
Post-Bac	5	50%
Major		
Biology	2	20%
Computer Science	1	10%
Geology	1	10%
Kinesiology	1	10%
Pre-Med	4	40%
Undecided/Undeclared	1	10%
Taken Gen Chem I before	3	30%
Taken Gen Chem II before	1	10%

Instrument

Based on the theoretical framework of epistemic cognition and the recommendations for measurement (Chinn et al., 2011), I developed the *Context-Specific Epistemic Aims and Source Beliefs Questionnaire* (CEASBQ; see Appendix A). The questionnaire assesses two dimensions of epistemic cognition—students' epistemic aims and epistemic beliefs about source of knowledge, specifically for online research of three chemistry-related topics[4].

Epistemic Aims and Source Beliefs

Under each chemistry topic, I developed two subscales of questions—epistemic aims and source beliefs. In the epistemic aims subscale, Questions 1 to 6 probe epistemic aims about establishing *true* vs. *false beliefs*, questions 7 to 12 assess aims about establishing *sufficiently* vs. *minimally justified beliefs*, and questions 13 to 17 tap epistemic aims about achieving understanding about the *explanatory connection of information* vs. a *list of isolated facts*.

In the source belief subscale, there are 3 subsets of items. Each subset has a unique question stem, which probes 1) the *sufficient condition* to believe (i.e., believing it as long as the information is from…), 2) the *necessary condition* to believe (i.e., believing it only if the information is from…, disbelieving it if the refutation is from…), and 3) the *sufficient condition to refute a held belief* (i.e., disbelieving it as long as a refutation is from…). The three subsets consist of the same 13 sources and an open-ended

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[4] The three topics are selected from the textbook (Tro, 2010) used in the General Chemistry II course, an second-semester introductory chemistry course required for students in science majors, on pre-professional track, and students in other science-related fields. General Chemistry II introduce students to thermodynamics, equilibrium, kinetics, electrochemistry, and descriptive chemistry. One of the prerequisites of General Chemistry II is to obtain a C- or higher grade in General Chemistry I.

question that asks for a brief explanation for the highest rated source(s). The sources that each subset comprises were chosen from the source-belief subscales of existing epistemic belief measures, including Hofer (2000) and Schommer (1990), and based on the interviews with students enrolled in the General Chemistry I in a prior study (Horvat et al., 2010).

Context Specificity

Context specificity of the measure manifests in two ways: 1) the medium—excerpts from a website, and 2) the content—three different chemistry topics. First, the general instruction sets a hypothetical scenario where students encounter three excerpts from an anonymous website, and treat these texts as a starting point of learning. The purposes of this instruction were to simulate a context of learning about topics pertaining to chemistry in web surfing, and to rule out students' presumption that the information in the excerpts is credible or trustworthy, and one from which they could acquire knowledge.

Second, in terms of content, there were three chemistry topics for the students to hypothetically learn, and the questions about students' epistemic aims and source beliefs were specifically tailored to learning these topics. The topics are 1) *the danger of antifreeze* (Tro, 2010, p. 632), involving chemistry knowledge about buffers, from the chapter on aqueous ionic equilibrium, 2) *heartburn* (p. 589), involving chemistry knowledge about acids and bases, from the chapter on acids and bases, and 3) *preventing the corrosion of iron* (p. 710), involving chemistry knowledge about oxidation, from the chapter on electrochemistry. The excerpts are from the "Key Concepts" section of the corresponding chapters of Tro (2010).

Response Scale

All questions used a response scale of 0 to 100, representing from complete disagreement to complete agreement, respectively. The use of 100 scale points (rather than using the coarse scale, such as 5- or 7-points) is supported by previous research that found positive effects of a larger number of scale points on reducing measure bias (Krieg, 1999), increasing reliability (Bandalos & Enders, 1996; Cicchetti, Showalter, & Tyrer, 1985; Lissitz & Green, 1975), and improving the fit indices of confirmatory factor analysis models (Green, Akey, Fleming, Hershberger, & Marquis, 1997).

Measure Length

There were a total of 56 items—17 for epistemic aims and 13 for source beliefs under each of the three chemistry topics. The total number of items on the pilot version of CEASBQ was 168.

Procedure

The pilot study involved two phases—the concurrent phase and the post-questionnaire phase, in which I collected three types of data, which include responses to the CEASBQ, the concurrent think-aloud while participants were responding to the questionnaire, and the retrospective verbal probing interview after completing the questionnaire. I administered all of the concurrent think-aloud and retrospective verbal probing with the participants. Students consented to participate in the study by signing an informed consent form and permission to audio record before the cognitive interviewing.

The Concurrent Phase

The interviewer explained to the participant that the purpose of the study was to understand the participant's experiences in responding to the questionnaire and interpretation and evaluation of the items and to improve the questionnaire. The interviewer emphasized to the participant that there were no “right” answers to the items, and that if there were clarity issues with the questionnaire they were not to be attributed to the participant, but rather an indicator of deficits with the questionnaire itself.

The interviewer instructed the participant to read aloud and to say what they were thinking while reading the instruction and responding to each item of the questionnaire. The interviewer explained to the participant that it was of utmost importance that the participant verbalize every thought he or she had during the process of taking the questionnaire. The participant was also informed that, if not verbalizing thoughts for more than three seconds, he or she would be politely prompted during the process with reminders such as, “Please say what you are reading” or “Please say what you are thinking.”

The interviewer then asked the participant to complete a short think-aloud training session with a non-chemistry passage about tsunamis and two items on a non-target epistemic dimension—structure of knowledge. In the training, participants asked questions, if they had any, about how to do the concurrent think-aloud and the interviewer provided clarification and further instruction to ensure the participant had understood the whole procedure before the formal think-aloud session started.

After the participant had been informed about and understood the requirements of the concurrent think-aloud, he or she was instructed to put on the microphone and begin to take the questionnaire. The participant accessed the questionnaire on a study-specific Blackboard™ site and completed it online. The completion of the questionnaire was not timed; the participant was given as much time as needed to complete the questionnaire.

The think-aloud session was recorded with two digital voice recorders. The interviewer administered the think-aloud protocol and prompted the participant to verbalize when necessary, and, in the meantime, observed and took field notes for the think-aloud.

The Post-Questionnaire Phase

After the participant completed the questionnaire and the concurrent think-aloud protocol, the interviewer conducted a retrospective verbal-probing interview with the participant, which was also audio-recorded. The interviewer used both prewritten probes and those emergent in the process of think-aloud (Table 2) to further explore the participants' experiences in taking the questionnaire and his or her epistemic aims and source beliefs in the online research on chemistry topics. The emergent probes included questions about participants' interpretation of a specific item, a part of the questionnaire instruction, one of the topics, as well as thoughts about epistemic aims or sources that were verbalized during the concurrent think-aloud.

Table 2

Verbal Probes for Retrospective Interviews

Examples of Pre-Written Probe	Examples of Emerged Probe
What are your overall impressions of the questionnaires?	What do you think the questions "I would believe the information in the post ONLY IF…" are trying to find out about you?
What do you think the questionnaire is trying to find out about you?	What did you mean by "credible sources"?

Table 2, continued

Examples of Pre-Written Probe	Examples of Emerged Probe
Which items do not make sense to you?	Why do you think your experiments would not help you learn about antifreeze?
What do you think about the topics?	Why did you give a low score to “thinking about different arguments” for the post about heartburn?
What do you think about the 0-100 scale for the answers?	Why did you consistently rate “many experts” higher than “chemistry professor”?

Data Analysis

Audio Data Transcription

The interviewer transcribed the audio data of both the concurrent think-aloud and the retrospective interviews. The concurrent think-aloud transcription was structured based on the instruction, 3 topics, and 168 items of the CEASBQ. A majority part of the concurrent think-aloud (i.e., a total of 168 units) was about the reason(s) for giving a certain score to an item. The mean length of the transcribed think-aloud was 6500 words per participant. There was minimal think-aloud content that was solely focused on the instructions for thinking aloud or on the content of the three topics. Part of the reason may be that each item refers to the content of the excerpt and the participants’ comments on the topics were also integrated with their thoughts about the items, which is well aligned with the design of the CEASBQ, and supports to the context-specific aspect of the questionnaire. Regarding the retrospective interview transcription, it was structured based on the questions asked. There was a mean of 8 questions (including the prewritten and the emergent questions) for each participants, which makes 8 meaning units. The mean length of the interview was 1500 words per participant.

The resultant transcription was 289 double-spaced letter-sized pages of text. The mean length of the transcription for each participant was 29 pages of text. The transcribed text was divided into units based on items and interview questions, which yielded 176 thought units for each participant. There were no unanswered items or questions by any of the participants in the present study.

Analytical Approaches

The main purposes of the cognitive pretesting were to understand how the respondents interpret the CEASBQ and their experiences in taking the questionnaire, and to obtain a preliminary understanding about college students' epistemic aims and source beliefs in the online research of chemistry topics. Both concurrent think-aloud and retrospective interview data were analyzed based on the coding schemes of 1) epistemic aims, 2) source beliefs, 3) item comprehensibility, 4) item scale and measure length, and 5) topic relevance. Under the scheme of epistemic aims, there are sub-schemes of a) true vs. false beliefs, b) sufficiently vs. minimally justified beliefs, and c) isolated facts vs. coherent connection of facts. Under the scheme of source beliefs, there are sub-schemes of a) multiple sources, b) criteria for developing beliefs, and c) criteria for refuting beliefs.

Results

RQ1: Students' Interpretations and Experiences

Item Interpretation

Students felt that items on epistemic aims were clear but some items on source beliefs seemed confusing, especially the necessary-sources subset. Few students captured the intended meaning of the question stem, "would believe…ONLY IF…" Six students misinterpreted it to be that given only one source, to what extent they would believe it; one student was inconsistent in his interpretation: for some items he understood the intended meaning but for others he did not.

Response Scale

Nine students thought the 0-100 response scale was interpretable. They reported treating it as percentage agreement. Although they claimed that the scale was unusual and that 7-point or 10-point scales would be enough, six participants provided finer-scaled responses (e.g., 18, 97) to the items.

Length of Questionnaire

Eight students reported the CEASBQ itself was an acceptable length. A large part of the 90-minute time was spent on verbalizing thoughts.

Chemistry Topics

Most students reported the chemistry topics were relevant to both their chemistry courses and everyday life.

RQ2: Epistemic Aims

Students gave high-score responses to items on developing true beliefs and avoiding false beliefs (See Table 3 for details). Few students explained why they want true information (Example 1). Students explained that false information may confuse them and would not be useful (Example 2). Those who responded not wanting true information explained that they had prior knowledge about the topics and already knew what is true (Example 3).

Endorsement for sufficiently justified beliefs was lower than for true beliefs. Students highly agreed that strong evidence for information would be helpful, but agreed less highly with items on thinking about multiple arguments and comparing different evidence. They explained that opposing arguments can be distracting (Example 4), that they do not have enough expertise to evaluate evidence (Example 5), and that they would not actively seek multiple justifications though it would be good to have multiple pieces of evidence presented to them (Example 6).

Interestingly, students endorsed both facts and explanatory connections as necessary for knowledge acquisition. Students endorsed seeking facts because they viewed facts as "truth" (Example 7) rather than focusing on whether the facts are isolated or connected, and they endorsed connections because they valued the explanatory function of logical connections and deemed that seeking facts and seeking connections are inseparable: knowing facts is necessary for making connections; making connections helps understand facts (Example 8). This finding does not rule out the possibility that learners may set lower-level epistemic aims of obtaining a list of isolated facts rather than grasping connections among facts (Chinn et al., 2011); however, it points out that facts and connections are orthogonal epistemic aims rather than opposite ends of a continuum, like true vs. false beliefs.

Table 3

Pilot Study Findings about Epistemic Aims and Source Beliefs and Supporting Quotes

Findings	Example #	Item	Score	Quote
Obtaining true beliefs	1	I would like to know what is true about antifreeze in the post.	100	P01: "Of course I want true information."
Avoiding false beliefs	2	I would like to avoid getting false information about corrosion of iron from the post.	100	P03: "Yes. False information would not be useful to me."
Obtaining true beliefs	3	I would like to get only the true information about antifreeze from the post.	30	P03: "…because I do know what is true in the post."
Considering different justifications	4	I would like to think about different arguments for the information about antifreeze in the post.	35	P01: "I personally don't want to think about arguments. They can be distracting."

Table 3, continued

Findings	Example #	Item	Score	Quote
Evaluating justifications	5	I would like to judge whether evidence is strong enough to support the information about heartburn in the post.	80	P04: I would like to judge, but I don’t know if I am qualified to judge. I would like to, but I don't feel that my skills are yet qualified for this.
Evaluating justifications	6	I would like to compare and contrast different evidences for the information about antifreeze in the post.	75	P05: “If different evidences are presented to me I would probably compare them, but I would not go out there and try to find them.”
Acquiring facts	7	I would like to know the facts about corrosion of iron in the post.	100	P07: “Yes, I would like the facts; I’d like to know what is factual about that.”

Table 3, continued

Findings	Example #	Item	Score	Quote
Acquiring connections among facts	8	I would like to grasp how the facts are connected about corrosion of iron in the post.	100	P07: “Also 100. Because I would like to know how the facts they are giving about electrode and water and the iron are connected, umm, how they might be related.”
Confirming with multiple sources	9	I would believe the information from the post if I read about it from a textbook.	70	P09: “If I heard from my chemistry professor about heartburn, I would believe it but I think I would still ask a medical doctor or look for other sources just to confirm the details.”
	10	I would disbelieve (no longer believe) the information from	60	P04: “If my chem professor told me you put three iron nails in water for a long time and they won’t rust, umm, it would surprise me, like

Table 3, continued

Findings	Example #	Item	Score	Quote
		the post if a chemistry professor told me about it.		a lot. I think I would ask him why and try to find more sources to back up that claim. Anyway, it would be very surprising. I would not trust him easily.
Holding higher standards for overthrowing held beliefs than developing new beliefs	11	I would believe the information in the post if I read about it from a chemistry journal article.	95	P03: “I would say a 95. Umm…they would have been peer-reviewed, they would therefore be more credible.”
	12	I would disbelieve the information in the post if I read about it from a chemistry journal article.	65	P03: “Umm, if something is against the norm, and if I know the norm, and it is just one article I would not disbelieve something. I would say 65, just because it is just ONE article. I would need to confirm with other sources.”

Table 3, continued

Findings	Example #	Item	Score	Quote
Viewing experimentation as facilitating deep understanding	13	I would believe the information from the post if I did an experiment to test the claim and the results confirmed it.	95 90	P02: "I did experiments to test this claim and the results confirmed it. If I did the experiment at home, if would be less. But if I did the experiment in the lab at school, it would be probably the same as the chemistry professor telling me. The experiment would still make me believe it…so pretty high, as high as the professor." P10: "Yes, most likely. My experiments always help get a better understanding, even if I did it wrong. But if I did an experiment and the

Table 3, continued

Findings	Example #	Item	Score	Quote
				results confirmed the hypothesis, I would believe it."
Believing experimentation but concerned about own ability to do experiments	14	I would believe the information in the post if I did experiments to test this claim and the results did not confirm it.	30	P01: "I often don't know what I am doing in my Chem experiments."
			40	P02: "No that's pretty low. There are a lot of things I can do wrong in my experiments."
			90	P03: "I did experiments to test this claim and the results confirmed it. 90. Because now my experiments would be overseen by the professor but there is still room for errors at my level of testing and experimenting."

RQ3: Source Beliefs

Students rated multiple sources equally high, for both developing and refuting beliefs (Table 3). The highest-rated sources were textbooks, professors, and confirmation by multiple experts, which suggests that students value multiple sources and that they deem these external testimonies as trustworthy. Students stressed that they need confirmation from multiple sources, even if they receive information from one of these trustworthy sources (Examples 9-10). Students also endorsed sources for developing beliefs ("would believe…if…") more highly than those for refuting held beliefs ("would disbelieve…if…"). They explained that the excerpts were largely consistent with their prior knowledge about the topics; therefore, one source, however trustworthy it is, would not be enough for them to overthrow long-held beliefs (Examples 11-12).

Another important finding about students' source beliefs concerns personal experimentation. Although not consistently rated as high as external testimony (e.g., textbooks), experimentation was endorsed by four students as highly trustworthy. These students explained that experimentation facilitates deep understanding (Example 13). Students who rated experimentation low were concerned about their levels of proficiency to correctly conduct experiments rather than experimentation itself. Most stated their errors in experiments often lead to unexpected findings, which made them trust their own experiments less (Example 14). That is, students endorse correctly conducted experiments as a way to acquire knowledge; however, when asked whether they believe experimentation as a source of knowledge, students often are more concerned about how well *they can do* experiments, which may explain the lower-level epistemic beliefs about personal experiments in prior survey research.

RQ4: Context Specificity

Students' responses to items on epistemic aims and source beliefs differed across topics (See Table 4 for details). First, each participant gave largely different scores to the same item when he or she answered across different topics (Example A). Second, topics differed in familiarity to the students. Some students claimed that they did not know what antifreeze was, which affected how they responded to items on *danger of antifreeze* (Example B). Third, topics were diverse in interdisciplinary nature. Some students stated that a medical doctor would be a better source for knowledge about heartburn, so they endorsed a chemistry professor lower on this topic (Example C). Finally, students stated that some topics (e.g., *danger of antifreeze*) were harder to test with chemistry experiments than others (Example D).

We found some epistemic aims (e.g., sufficient justification, connections of facts) have higher-level context specificity than others (e.g., true beliefs). We believe that was because 1) participants think collecting isolated facts is a necessary step to making connections among facts to grasp the "big picture", and that evaluating multiple arguments should be built on a solid understanding of one knowledge claim, and 2) setting specific epistemic aims is highly dependent on the individual's knowledge of and proficiency with the content to-be-learned. Provided with a topic about which she has little prior knowledge, a learner may set lower-level epistemic aims (e.g., acquiring facts, seeking minimal justification); as learning progresses and understanding deepens, she may set higher-level epistemic aims for the same topic (e.g., evaluating arguments, comparing evidences, seeking understanding of the connections among facts).

Table 4

Pilot Study Findings about Context Specificity and Supporting Quotes

Finding	Example #	Item	Quote
Largely difference in responses to the same item under different topics	A	I would like to think about different arguments for the information about ____ in the post.	P01: for **antifreeze**, 30. "I don't know anything about antifreeze. I don't think I need to think about DIFFERENT arguments. That would only confuse me."
			P01: for **corrosion of iron**, 90. "Yeah, it would be good to think about different opinions about how to prevent iron from rusting."
			P01: for **heartburn**, 100. "I really think there are more ways to cure heartburn than just taking antacids."
Diversity in familiarity	B	Topics (e.g., antifreeze, heartburn)	P01: "Ethylene… gly…col, the main component of antifreeze, is metabolized by the liver into glycolic acid. Umm, I don't know what **antifreeze** is."

Table 4, continued

Finding	Example #	Item	Quote
			P01: "I do know all of the terms in the passage about **heartburn**."
Diversity in interdisciplinary nature	C	I would believe the information in the post if my chemistry professor told me about it.	P06: "A chem professor would know the acids and bases part of **heartburn**, but I think a medical doctor, like my PCP, would know things about heartburn equally well, and probably even better."
			P06: "Yeah, **corrosion of iron** is pretty much all chemistry. I would believe it if my chem professor told me about rusting."
Diversity in feasibility of experimentation	D	I would disbelieve the information in the post if I did experiments to test this claim	P04: "I don't know how you could do an experiment on people consuming **antifreeze**, but if I did it and nobody died from it I would definitely disbelieve the information."

Table 4, continued

Finding	Example #	Item	Quote
		and the results did not confirmed it.	P04: Let's see, if I put **iron** nails in a bucket of water for a year and they did not rust…yeah, I would definitely no longer believe what it says in the post."

Discussion

Using a cognitive pretesting method, I obtained evidence that supports the cognitive validity of the *Context-Specific Epistemic Aims and Source Beliefs Questionnaire* (CEASBQ). I found from a sample of 10 college students from one chemistry class that when conducting online research on chemistry topics, college students held epistemic aims for true beliefs, sufficiently justified beliefs, and explanatory connections between items of information. Students resorted to multiple sources to achieve these epistemic aims during the process of online research. Furthermore, they required more sources and had higher standards for these sources for them to refute long-held beliefs compared to developing new beliefs about the chemistry topics in research.

Methodological Implications and Measure Revision

Findings from the pilot study have important methodological implications, especially for revising and improving the CEASBQ. First, to address the issues of item incomprehensibility and length, I deleted the section on *Necessary Sources to Develop Beliefs* from all three topic-specific measures. The revision results in a deletion of 13 items from each topic-specific measure (i.e., 39 from the entire CEASBQ). The new source beliefs subscale consists of 2 sections—sources for developing new beliefs and sources for refuting held beliefs.

To address the minor concerns about the response scale (0-100), I added instruction about the scale, "…on a scale of 0 (complete disagree) to 100 (completely agree), which can be thought as the percentage (0-100%) of your agreement on each statement." This addition may help students better understand the response scale and quantify their endorsement.

Second, the issue with questions (Q13-17) on *isolated facts vs. connected items of information* was that they were conceived as emphasizing *facts* (i.e., true beliefs) rather than *isolated* facts (i.e., disconnected items of information). From the think-aloud data, I found that students sought both facts and explanatory connections of facts, which implies the two are divergent dimensions rather than two opposite poles of one dimension. The finding highlights the crucial issue of differentiating in operationalization the dimension of true beliefs from the dimension of isolated facts vs. connection of facts. The latter ought to be operationalized with emphases on *connected* (as opposed to *isolated*) and *explanatory* (as opposed to *lack of logic*) rather than on *facts*, for *facts* may be easily conceived as having the same meaning as *truth* (i.e., the dimension of true beliefs), making the items fail to tap the intended aspect of epistemic aims. The original items did not sufficiently stress the key concept—*explanatory connection* (as opposed to isolated items of information). Therefore, I replaced two items with those that emphasized the explanation and logical connection aspect. For instance, "I do not want to understand why it is dangerous to consume antifreeze" and "After reading the post, all I need to remember is the fact that antifreeze is dangerous for human body."

Third, to address the minor concerns that some of the sources listed on the CEASBQ were not Internet-based, I revised the items in the source beliefs subscale to reflect both the nature and the medium of the sources. For instance, I revised the original question stem "…a chemistry professor told me about it" to "…it was posted by my chemistry professor on our course Blackboard site," and I revised the original question stem "…it is on debate in the field of chemistry. Some experts hold this view; some don't" to "…it was one of the posts in an online discussion, in which scholars and experts in chemistry participate." I have also added examples for abstract source types to facilitate participants' responses. For instance, "…it was from an online scholarly journal article, for example, *Science*," and "…it is from an online encyclopedia, e.g. Wikipedia, or www.about.com."

Conclusion

In this pilot study I demonstrated the cognitive validity of the CEASBQ with the method of cognitive interviewing. The findings have invaluable methodological implications, which helped point out aspects of the measure that needed further improvement. In addition, the think-aloud data informs how to differentiate in operationalization the dimension of true beliefs from the dimension of isolated facts vs. connection of facts. I revised the CEASBQ accordingly for the larger scale study, which may yield more informing and reliable results about college students' context-specific epistemic cognition in online research on chemistry topics.

CHAPTER 4. METHODOLOGY

The goals of the dissertation study were to explore college students' context-specific epistemic aims and epistemic beliefs about sources, and to examine how these two dimensions of epistemic cognition may be associated with learning outcomes in an Internet-based learning context in which students conduct online research for three chemistry topics. I sought to understand what epistemic aims, if any, students set when conducting online research on chemistry topics. I investigated whether they held beliefs about multiple sources of knowledge, and if so whether they trusted sources differently for believing versus refuting information. I aimed to examine whether students' epistemic aims and source beliefs were specific to the topics in research, and furthermore whether these epistemic cognitions may influence students' Internet-based learning outcomes.

In the remainder of this chapter, I will provide the methodological details for the dissertation study on the following aspects: (1) the context of the study site, (2) participants, (3) study procedure, (4) measures, (5) data screening and analysis, and (6) sample size estimation for key analytical approaches.

Study Context

Participants were recruited from two college-level introductory chemistry courses—General Chemistry I (CHEM 1031) and II (CHEM 1032). They are the first- and second-semester chemistry courses for science majors, pre-professional students, and other students in science-related fields. CHEM 1031 is a quantitative introduction to atomic and molecular structure, states of matter, basic thermodynamics, and solutions. CHEM 1032 is a quantitative introduction to thermodynamics, equilibrium, kinetics, electrochemistry, and descriptive chemistry, for which passing CHEM 1031 is a prerequisite. Each of the two courses includes 4 benchmark exams (each 100 points) worth 300 points in total with the lowest dropped, a final exam worth 200 points, lecture and recitation quizzes worth 100 points, and all homework assignments worth 100 points. Students' course grades (a maximum raw score of 700 points for each student) may be standardized within class and converted to letter grades A (90-100), B (80-89), C (70-79), D (60-69), and F (0-59). Students have to pass CHEM 1031 with a grade higher than C- to be eligible for CHEM 1032 enrollment.

The structures of CHEM 1031 and CHEM 1032 are identical. Each course includes lectures and recitations throughout the semester. Each lecture class consists of approximately 150 – 200 students taught by a chemistry professor. The class meets 3 times per week for lecture. The classes are in traditional lecture form with use of lecture notes presented with slides (e.g., PowerPoint). Recitations are small sections of about 30 students taught by an instructor (typically a graduate teaching assistant) under the supervision of the lecturer. The recitation instructor reviews material that helps students prepare for exams. Recitations are designed for students to ask questions about the lecture material and the exercises or problems encountered in the textbook or other course materials.

Participants

Recruitment

In the first week of the Spring 2014 semester, I recruited study participants from two CHEM 1032 lecture classes at Temple University in Philadelphia, Pennsylvania. In the 5th week of the Spring 2014 semester, I recruited another cohort of study participants from one CHEM 1031 lecture class at the same university.

The recruitment procedures for both cohorts were identical. I recruited participants via an in-person announcement in class. The recruitment was conducted at the end of a lecture for each class to ensure all students in the class receive the announcement. At the recruitment, I presented a 5-minute introduction to the study with a set of PowerPoint slides. Following the presentation, I asked students to sign up for participation. Students who wished to participate wrote down their name and Temple email address in the slot on a pre-made timetable corresponding to a time and date for them to complete the survey.

Sample Characteristics

A total of 354 students from two classes participated in the study ($n_{\text{CHEM1032}} =$ 227). As shown in Table 5, the sample was diverse in terms of ethnicity, gender, and socioeconomic status, and includes comparable numbers of female and male students. Participants were age 18 or older at the time of participation in the study. A majority of the sample were freshmen and sophomores. The demographics of the participants were very representative of the students in the General Chemistry courses, and representative of the students in STEM majors or on pre-professional tracks at Temple University.

Table 5

Participant Demographic Information

Demographic Variable		Frequency (*n*)	Percentage (%)
Class		354	100
	CHEM 1031	127	35.9
	CHEM 1032	227	64.1
Major		354	100
	STEM	209	59
	Non-STEM	132	37.3
	Undeclared or undecided	13	3.7
Sex		354	100
	Female	217	61.3
	Male	137	38.7
Race		354	100
	White	180	50.8
	Middle Eastern	12	3.4
	Indian subcontinent	37	10.5
	Hispanic/Latino	12	3.4
	Black	33	9.3
	Asian	66	18.6
	Other	14	4

Table 5, continued

Demographic Variable	Frequency (*n*)	Percentage (%)
Mother’s Educational Attainment	354	100
Did not graduate from high school	25	7.1
Graduated from high school	83	23.4
Some college/community college	73	20.6
Bachelor's degree	106	29.9
Graduate/professional degree	67	18.9
Father’s Educational Attainment	354	100
Did not graduate from high school	28	7.9
Graduated from high school	80	22.6
Some college/community college	68	19.2
Bachelor's degree	101	28.5
Graduate/professional degree	75	21.2
Year in College	354	100
Freshman	193	54.5
Sophomore	82	23.2
Junior	44	12.4
Senior	31	8.8
Post-baccalaureate	4	1.1
CHEM 1031 Students’ Prior Experience in Course	127	100
No	83	65.4

Table 5, continued

Demographic Variable	Frequency (*n*)	Percentage (%)
Yes	44	34.6
CHEM 1032 Students' Prior Experience in Course	227	100
No	210	92.5
Yes	17	7.5
	N	*M* (*SD*)
Age	354	19.7 (2.3)

Informed Consent

The approved informed consent form was developed based on the consent form template for minimal risk social and behavior research provided by the Institutional Research Board of Temple University. The consent informs the participant of (1) the title of the research study, (2) name and department of the study investigator, (3) the purpose of the research, (4) estimated duration of the participation, (5) study procedure, (6) risks and benefits, (7) the alternative to participation, and (8) confidentiality. The consent was printed on letter-size paper. The participants were asked to sign the consent form with pen rather than pencil. After signing the consent form, each participant was assigned a unique participant number, which was the only identifier for that participant's data in the study.

Incentive

Students participated in the study in exchange for 1% of course grade worth of extra credit for the course from which they were recruited. Students who chose not to participate in the study had the option of completing an extra-credit assignment provided by the lecturer for the same amount of extra credit. Participants were clearly informed that the extra credit was awarded for their *participation* in the study (or completion of alternative assignment), rather than for their *performance* in the study (or on the alternative assignment). In other words, as long as they completed the survey (or alternative assignment) they would get the extra credit.

Procedure

Time

The data collection sessions were held in the third to fifth weeks of Spring 2014 for participants from CHEM 1032 and in the fifth to sixth weeks for participants from CHEM 1031. There were multiple sessions per day to accommodate students' schedules for participation. Each session lasted for approximately 50 minutes, which included time for reading and signing informed consent and completing the survey. The survey itself took approximately 45 minutes to complete.

Location and Medium

The study sessions were held in a computer lab on campus. Participants were invited to a small-group session[5] in this computer lab for the study. Each participant signed a hard copy stamped informed consent form, and then a participant number was assigned to the participant as an identifier within the study, so that no name or school ID was associated with information provided by the participant. Participants then accessed a virtual folder containing three topic-specific questionnaires on the study-exclusive Blackboard™ site using a lab computer. In order to further protect participants' privacy,

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[5] The capacity of the computer lab is 27 people.

the communication tools of the Blackboard™ site were disabled so that no between-participant communication could be conducted.

Measures

Demographic Questionnaire

The demographic questionnaire (Appendix B) asked for participants' background information. The questions asked about the participant's age, sex, race, parent education, year in college, and previous enrollment in CHEM 1031 and CHEM 1032.

Epistemic Aims and Source Beliefs

I used the revised *Context-Specific Epistemic Aims and Source Beliefs Questionnaire* (CEASBQ; Dai & Cromley, 2014, April) to assess college students' two epistemic cognition components in a simulated Internet-based learning context. The content of the revised CEASBQ (See Appendix C for details) remained the same as in the original version, which consisted of three topics and two subscales—epistemic aims and source beliefs—under each topic.

Measure Design

The three-topic design and instruction. There were a total of three topic domains in which the main questionnaire was situated. The topics are 1) *the danger of antifreeze*, involving chemistry knowledge about buffers, from the chapter on aqueous ionic equilibrium (Tro, 2010, p. 632), 2) *heartburn*, involving chemistry knowledge about acids and bases, from the chapter on acids and bases (p. 589), and 3) *preventing the corrosion of iron*, involving chemistry knowledge about oxidation, from the chapter on electrochemistry (p. 710). The content in the webpage posts were excerpts from the "Key Concepts" section of the corresponding chapters of Tro (2010).

In each measure in a topic domain (e.g., *Antifreeze*), there was a picture showing multiple research results returned by a search engine and a clicked-opened webpage on which there was a post titled, *The Danger of Antifreeze*. There was also a set of instructions that informed participants 1) to read the presented post for information about antifreeze, and then 2) to answer three sets of questions (i.e., on epistemic aims, source beliefs, and learning outcome) in the main questionnaire. The possible clues (e.g., URL, author, publisher, etc.) for where the post might come from were blocked from the participants. The assumption was that they did not know where the post was from or how trustworthy it was.

The setup of three topic domains and the instruction of the CEASBQ served the purpose of operationalizing context specificity. Specifically, the CEASBQ manipulated one aspect of a context (i.e., topics of research), and kept other aspect of the context the same (e.g., the same task of online research, same time, same location). As such, the context was specified with differences in the topic of research.

Sections in each topic-specific questionnaire. In the main questionnaire in each topic domain, there were 3 sections of questions—Section A on mastery goals[6] and epistemic aims, Section B about source beliefs, and Section C which asked substantive questions about the learning topics (learning outcome)[7]. Items in Section A tapped mastery goals and epistemic aims. The answer to each item was on a scale of 0 (*completely disagree*) – 100 (*completely agree*). There were a total of 26 items, with Items 1 – 8 assessing mastery goals, 9 – 14 tapping true vs. false beliefs, 15 – 20 tapping

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[6] A following section in Measures, *Mastery Goal Orientation*, will provide details about the items.
[7] A following section in Measures, *Internet-Based Learning Outcome*, will provide details about the items.

sufficient vs. minimal justification, and Items 21 – 26 tapping epistemic aims for explanatory connections of information.

Items in Section B tapped source beliefs. There were a total of 14 sources used to probe students' source evaluation under 2 different conditions—when the presented information was hypothetically from a source (what would you trust-to-believe), and when the presented information in the post contradicted a source (what would you trust-to-refute). Thus, the 14 sources were rated twice, each time in a unique condition, which resulted in 28 ratings (14 sources × 2 conditions). Participants provided their rating of each source based on how trustworthy a source was, on a scale of 0 (*not at all agree I would believe/no longer believe*) to 100 (*completely agree I would believe/no longer believe*).

The Trust-to-Believe questions[8] had students directly rate the sources, by hypothesizing if the presented post was from each source (of the 14 sources). Students rated to what extent they trusted the 14 sources for them to learn about a topic; that is, to develop new beliefs or learn new information. The Trust-to-Refute questions[9], on the other hand, added another variable into consideration—the issue of confirmation. Essentially, students were instructed by the questions to check the post against each of the 14 sources, which consisted of contradictory information about the topic in research. In this case, students rated to what extent they trusted the 14 sources for them to refute information about the topic presented in the post.

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[8] A Trust-to-Believe question about source is, "I would **believe** the information about [name of topic] in the post **if it is from** [source name]."
[9] A Trust-to-Refute question about source is, "I would **no longer** believe the information about [name of topic] in the post **if it is inconsistent with** [source name].")

Length. In the main questionnaire in each topic domain, there were a total of 54 items (26 on goals and 28 on source beliefs) that assess students' topic-specific epistemic cognitions.

Measure Validity

Content validity. Although further validation of revised CEASBQ is one of the study goals, there has been support for the content validity of the measure. First of all, the draft of the CEASBQ was carefully developed based on a comprehensive theory by Chinn and colleagues (2011) and revised multiple times, so that the items faithfully express the theoretical meaning of the constructs. Second, the measure development strictly followed the methodological recommendations by Chinn and colleagues (2011), in terms of reflecting the context specificity, assessing finer-grained cognitions, and asking for qualitative explanations for the quantitative responses. Third, two authors of the Chinn et al. framework (2011) reviewed a developed draft of the CEASBQ and endorsed on the content validity of the measure. I also revised the draft based on the authors' feedback on improving the clarity of wording and enriching the collection of sources.

For the chemistry topics of the measure, validity is strengthened because the passages on the chemistry topics were directly quoted from the textbook used in both courses (Tro, 2010)[10]. Two chemists (both PhDs and with at least 3-year experiences teaching the co-requisite chemistry labs of Gen Chem I and Gen Chem II) also provided feedback on choosing chemistry topics for the CEASBQ, and endorsed the final selection of the three topics. Both of the Gen Chem II professors endorsed the selection of the

[10] Tro (2010) is the textbook for both Gen Chem I and II courses: the former covers the first 10 chapters, and the latter covers Chapters 11-18.

topics. Participants in the pilot study all endorsed the relevance of the three chemistry topics.

Cognitive validity. Findings from the pilot study provided evidence for the cognitive validity of the CEASBQ. After the revisions, I improved the item comprehensibility by deleting a confusing subscale (i.e., necessary sources for developing new beliefs) and rephrasing items that did not tap the intended construct (i.e., two items on *facts*). I edited the instruction to facilitate participants' understanding of the study context and the response scale. The revised CEASBQ has stronger validity evidence than the CEASBQ used in the pilot study.

Measure Reliability

For the section on epistemic aims, the items within each subscale were developed consistently based on the theoretical meaning of the construct. The internal consistency within subscales was adequate in all three topic domains (.780 ~ .871; Table 6).

The section on source beliefs contained a variety of actual sources, and probed students' evaluation without providing aspects of evolution. It is expected that there would be a considerable amount of error variance. It appeared that the subscale internal consistency was adequate in both conditions in all 3 domains (.868 ~ .901; Table 6).

Table 6

Subscale Internal Consistency of the Main Questionnaire

Subscale	*N*	# of Items	Cronbach's α
Antifreeze			
Section A.			
Mastery Goals	353	8	.906
True Beliefs	354	6	.871
Justified Beliefs	353	6	.797
Explanatory Connection	354	6	.798
Section B.			
Trust-to-Believe	250	14	.873
Trust-to-Refute	348	14	.884
Corrosion			
Section A.			
Mastery Goals	352	8	.927
True Beliefs	353	6	.78
Justified Beliefs	354	6	.825
Explanatory Connection	352	6	.783
Section B.			
Trust-to-Believe	353	14	.868
Trust-to-Refute	351	14	.886

Table 6, continued

Subscale	*N*	# of Items	Cronbach's α
Heartburn			
Section A.			
Mastery Goals	353	8	.899
True Beliefs	353	6	.805
Justified Beliefs	351	6	.794
Explanatory Connection	349	6	.792
Section B.			
Trust-to-Believe	352	14	.876
Trust-to-Refute	348	14	.901
Across 3 Topics: Sections C			
Online Learning Outcome	345	15	.742*

* Ordinal alpha (Zumbo, Gadermann, & Zeisser, 2007).

Mastery Goal Orientation

In order to further test the construct validity of the epistemic aims subscale, I adopted the scale on mastery goals from Patterns of Adaptive Learning Scales (PALS; Midgley et al., 2000) and that on mastery approach goals from (Elliot & McGregor, 2001) to measure students' mastery goals in the context of online research. I modified the items so that they were specific to the three chemistry topics, instead of the original context—"in class this year" (Midgley et al., 2000, p. 10) and "in this class" (Elliot & McGregor, 2011, p. 504). There were a total of 5 mastery goal orientation item in the

PALS, with a high Cronbach's α of .85. There were 3 items on mastery-approach goals in Elliot and McGregor's (2011) scale, with a high Cronbach's α of .87.

I integrated these 8 items in the Section A of each topic-specific measure (i.e., Item 1-8), and make the response scale of these items the same as the rest of the questionnaire (i.e., 0-100; see Appendix C). The mastery goals subscale had high internal consistency in all three topic domains (.899 ~ .927; Table 6).

Perceived Competence with Sources

Based on results of the pilot study which revealed a role for students' perception of competence in processing different sources, I developed items assessing perceived competence with each of the 14 sources to further examine whether students' source beliefs would be affected by their perceived competence with sources. I constructed a question for each source tapping perceived competence in processing it. The question stem is, "My ability to understand [name of a source] is____" (except for the lab experiment source, for which the question is, "My ability to conduct chemistry experiment is ____.")

The response scale to these perceived-competence items is 0 (*completely unable*) – 100 (*completely able*). This scale on perceived competence with sources was placed after the demographic questionnaire and before the three topic-specific measures (See Appendix C). The internal consistency was high for this measure of perceived competence for learning from the 14 sources ($\alpha = .924$).

Internet-Based Learning Outcome

In each main questionnaire in a topic domain, the last section of questions—Section C—measured the learning outcome on the topic using the presented webpage post (See pp. 114-117 for details about Sections A and B). Specifically, Section C examined students' comprehension of and application of information from the webpage post. In order to correctly answer the questions in the learning outcome measure, students needed to comprehend the content in the post and the additional information provided in each item, be able to make connections between the post and the questions, and be able to apply concepts and principles in the post to situations given in the questions. No prior knowledge about the topics was required, and minimal prior knowledge from high-school level chemistry was needed (e.g., atoms are made up of electrons, neutrons, and protons). The students may reread the post to answer the questions, if needed.

There were a total 5 multiple-choice questions in Section C on each of the three topics—Antifreeze, Corrosion, and Heartburn, resulting a total of 15 questions that assessed online learning outcomes.

I developed the measure based on relevant content in Tro (2010) and credible sources, such as the official website of National Institutes of Health (nih.gov). I verified and revised the content with the help from two chemistry PhDs. Both chemistry course professors read the measures and approved the content validity and its relevance to course content. The internal consistency of the measure was acceptable (ordinal $\alpha = .742$)[11].

Prior Achievement and Prior Knowledge

Recall that students were from two different chemistry courses, and that CHEM 1031 was a prerequisite for CHEM 1032. For participants from CHEM 1032, their grades

[11] Internal consistency tends to be underestimated with binary variables using Cronbach's alpha. Using polychoric correlation matrix, ordinal alpha (Zumbo et al., 2007) provides unbiased estimate of internal consistency.

in the prerequisite CHEM 1031 course were obtained from the Department of Institutional Research of the university as a measure of prior achievement in chemistry. For the CHEM 1031 students, however, their prior achievement in chemistry was measured with scores on the first course benchmark exam.

An important difference between the two cohorts was that CHEM 1032 participants had learned from the prerequisite CHEM 1031 course about the related chemistry knowledge of the three topics involved in the main questionnaires. (i.e., buffers for *Antifreeze*, oxidation for *Corrosion*, and acids and bases for *Heartburn*). CHEM 1031 participants, on the other hand, had not been taught about the related chemistry knowledge. Thus, the class membership variable should to some extent reflect differences in prior knowledge.

Data Analysis

Missing Data

There were minimal missing data in the study. Most of the missing data were on the prior achievement variables and were due to lack of student consent to release grades or exam scores. I examined the proportion of missing data on the goals, source beliefs, and learning outcome variables: to see 1) whether there are more than 5% of data missing for each observation and 2) whether there are more than 5% of data missing for each variable. Neither of the above conditions was met. In the main analyses, such as multitrait-multimethod model estimation and path analysis, I used a maximum likelihood estimator to ensure unbiased estimates of parameters of interest.

Data Clustering

As discussed in the section on study context, the sample consisted of students from CHEM 1031 and CHEM 1032. I examined the intra-class correlation of the learning outcome scores to examine whether data were dependent within class. An ICC of .042 (i.e., < .05; Bickel, 2007) indicated that learning outcome scores were not nested within class and that there was no need to account for data dependency in the related analyses.

Analytical Approaches

There were three main research objectives including validating context-specific epistemic aims, examining beliefs about multiple sources, and investigating the relationship between epistemic cognition and learning outcomes in the online research of three topics. In this section, I present analytic approaches for each objective.

Validation of Context-Specific Epistemic Aims

The method of multitrait-multimethod analysis (MTMM; Campbell & Fiske, 1959) was adopted for analyzing construct validity (Cronbach & Meehl, 1955) and context specificity of epistemic aims. The main purposes were to validate the existence of a theoretical construct (i.e., *epistemic aims* for true beliefs, justified beliefs, and explanatory connection), and to partial out the variations produced by the construct from the total variance in the subscale scores (Borsboom, Mellenbergh, & van Heerden, 2004). The MTMM analysis has been widely used to establish construct validity (i.e., convergent validity and divergent validity) of psychological measures, and is therefore seen as a cornerstone for construct validation (Lance et al., 2009). There are a number of quantitative approaches to analyzing MTMM data, however, a confirmatory factor analysis (CFA) approach examining the correlations among traits and the ones among methods, has been argued the most faithful to Campbell and Fiske's criteria (1959) for convergent and discriminant validity (Lance et al., 2009).

RQ1a. Construct validity of epistemic aims. I used a CFA approach to conduct the MTMM analyses for data on epistemic aims. As described earlier, the revised CEASBQ comprised 3 different chemistry topics, which were modeled as 3 different "method" factors. The 3 types of epistemic aims and mastery goals were modeled as the "trait" factors in the MTMM models. The 12 subscale scores served as manifest variables in the MTMM models, which made a total of 78 elements in the input variance-covariance matrix.

To test the construct validity for epistemic aims, a series of CFA models were constructed. Model a (Figure 2) was a correlated-trait correlated-method, hypothesizing that mastery goals and epistemic aims were distinguishable and contributed to subscale-score variance. Model a was compared to a series of alternative models for validation.

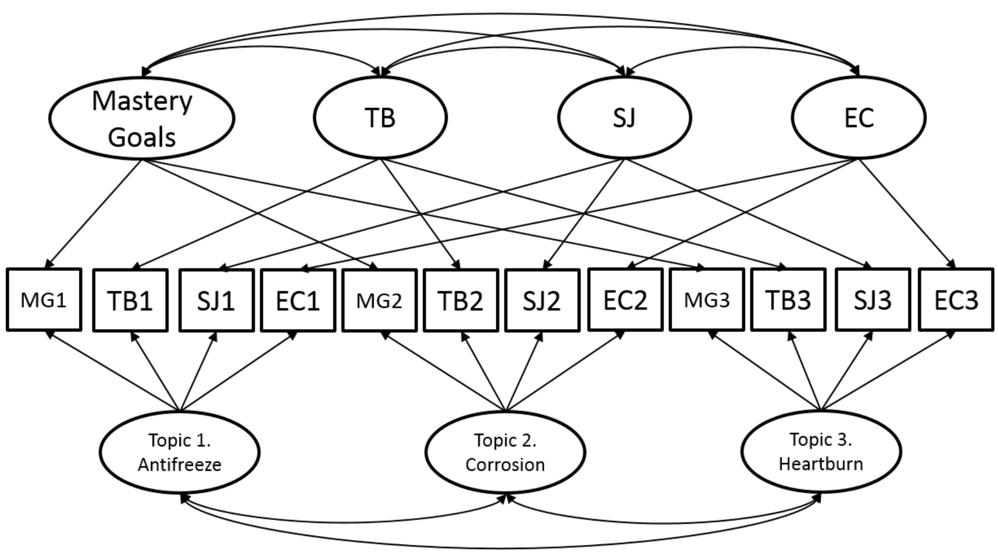


Figure 2. Correlated-trait correlated-method model of a mastery-goals factor and three epistemic-aims factors—true beliefs, sufficiently justified beliefs, and explanatory connections in online research on three chemistry topics (Model a). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model b (Figure 3) was specified to be a no-trait correlated-method, which hypothesized that no variance in subscale scores was explained by any trait factor. Model c was specified to be a one-trait correlated-method, which hypothesized that there was one trait—general goals—contributing to variance in subscale scores (Figure 4). Model d was specified to be a two-trait correlated-method model, which hypothesized that mastery goals and an epistemic-aims construct contributing to the variance in subscale scores (Figure 5).

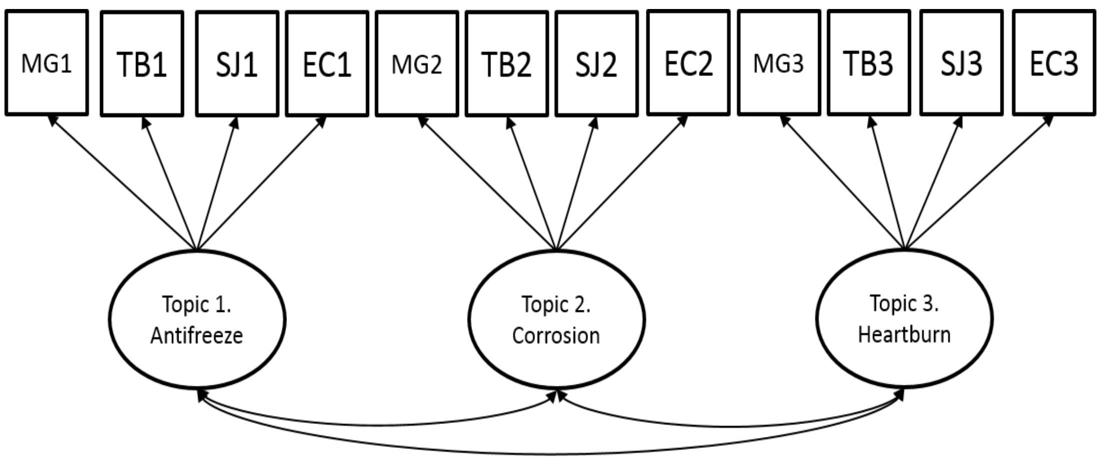


Figure 3. No-trait correlated-method model without aims/goals factors (Model b). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

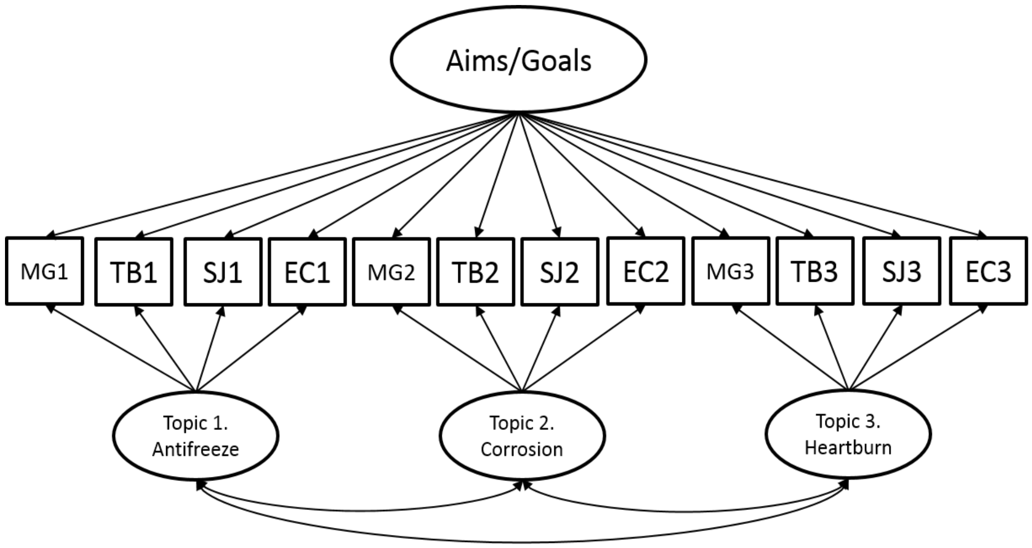


Figure 4. One-trait correlated-method model of a general aims/goals factor (Model c). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

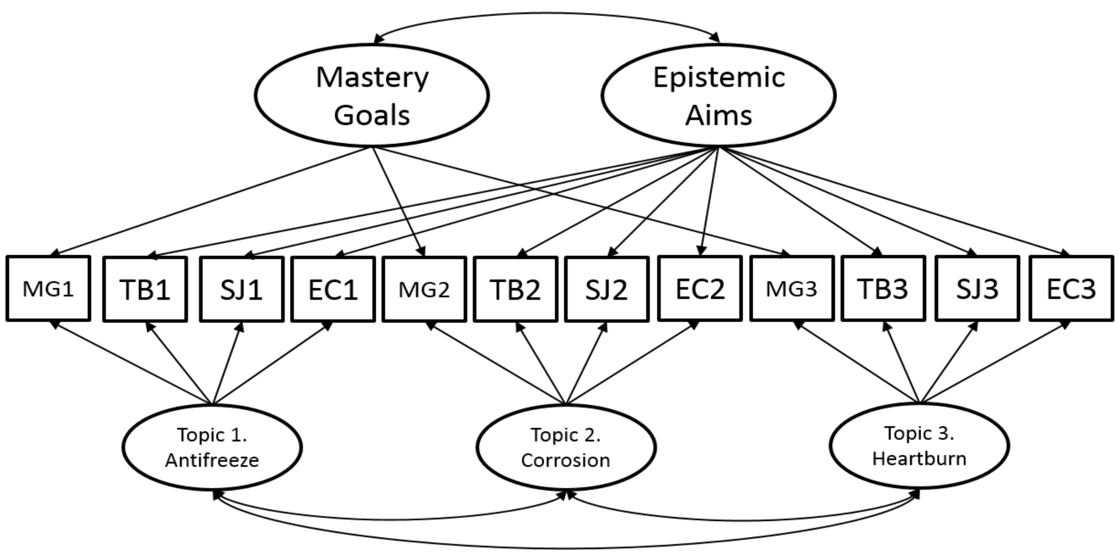


Figure 5. Two-trait correlated-method model of a mastery-goals factor and a general epistemic-aims factor (Model d). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Models e – g (Figures 6 – 8) were specified to be 3 different three-trait correlated-method models, which hypothesized that mastery goals and each of the epistemic aims should be combined, and that this combined goal and two epistemic aims together contributed to the variance in subscale scores.

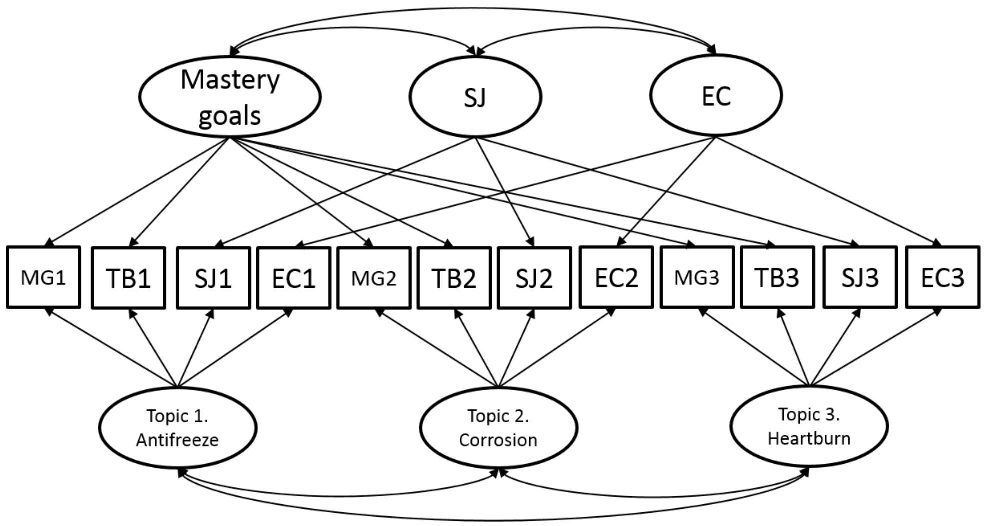


Figure 6. Three-trait correlated-method model of a mastery-goals factor, a justified-beliefs factor, and an explanatory-connection factor (Model e). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

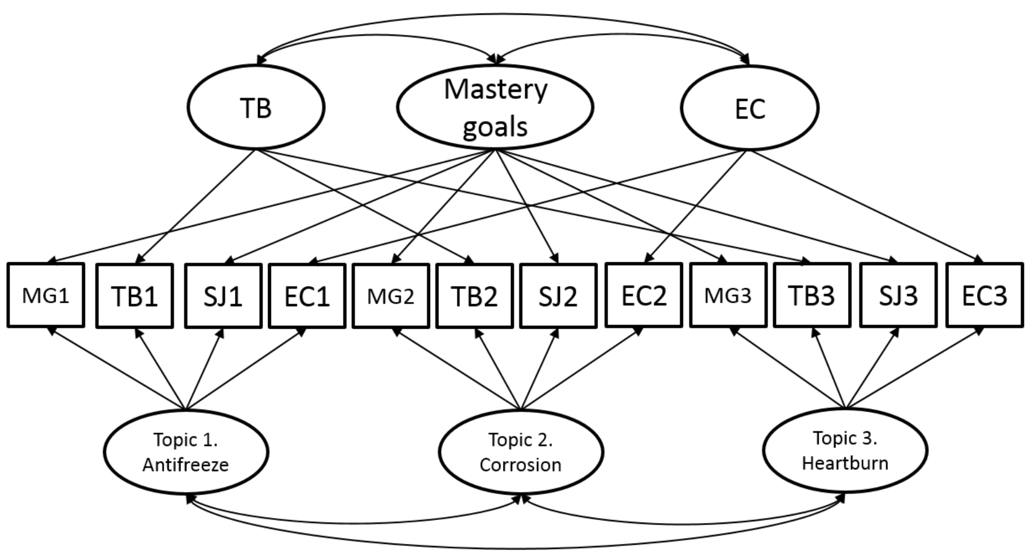


Figure 7. Three-trait correlated-method model of a mastery-goals factor, a true-beliefs factor, and an explanatory-connections factor (Model f). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

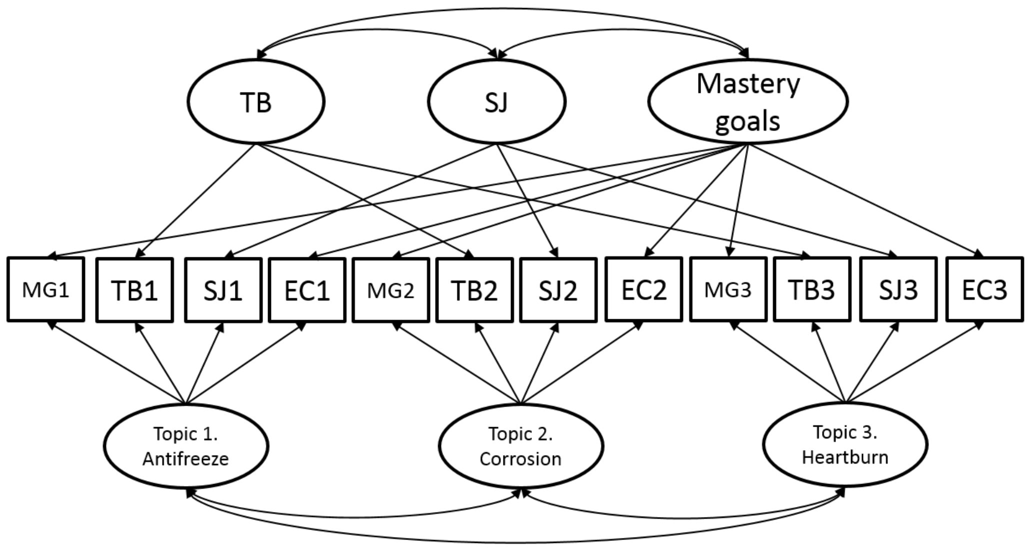


Figure 8. Three-trait correlated-method model of a mastery-goals factor, a true-beliefs factor, and a sufficiently-justified-beliefs factor (Model g). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connections

Models b – g were each compared with Model a in terms of goodness-of-fit. The best fitting model was retained as the final model (i.e., there are indeed multiple distinct constructs; Byrne, 2012).

Comparison #1 (Model a vs. Model b) would provide support for the construct convergent validity of the three epistemic aims and the mastery goals construct. Comparisons #2 (Model a vs. Model c), #3 (Model a vs. Model d), #4 (Model a vs. Model e), #5 (Model a vs. Model f), and #6 (Model a vs. Model h) together would provide support for the construct discriminant validity of epistemic aims. Specifically, Comparisons #4 to #6 would provide evidence for the discriminant validity of the three epistemic aims—true beliefs, justified beliefs, and explanatory connections—from the construct of mastery goals in achievement goals theory.

RQ1b. Context specificity of epistemic aims. As discussed in the Measure section, the context specificity in this the measure of epistemic cognition is mainly manifested by the specifying three different topics in chemistry. In order to test the context specificity epistemic aims, a correlated-trait one-method model (Model h; Figure 9) was constructed and compared to the best fitting model from the prior comparisons.

Model a outperforming Model h indicated that the context-related variance was contributed by multiple chemistry topics rather than a single subject domain (i.e., chemistry), suggesting context specificity of the epistemic aims.

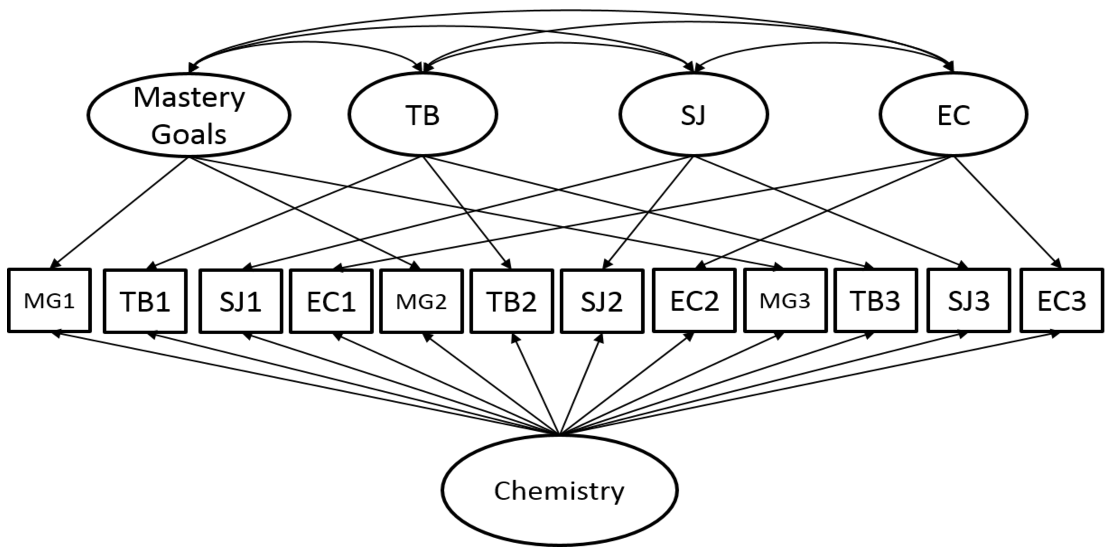


Figure 9. Correlated-trait one-method model of a mastery-goals factor and three epistemic-aims factors—true beliefs, sufficiently justified beliefs, and an explanatory-connections factor in online research on three chemistry topics (Model h). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

RQ1c. Subscale reliability. To examine the subscale reliability for each of the three types of aims within the section on epistemic aims, I decomposed the subscale-score variance (σ^2) using the model coefficients of the correlated-trait correlated-method model (Model a). According to classical test theory, the total variance of the subscale scores can be decomposed into true-score variance and error variance, which provides evidence for subscale reliability. In addition, due to the multitrait-multimethod structure of the data, the true-score variances could be further decomposed to variance contributed by traits (i.e., goals) and by methods (i.e., topics), which indicates the trait consistency and method specificity of the measure. The total variance was composed of three types of variances—trait effects, method effects and measurement errors:

(1) $\sigma^2_{total} = \sigma^2_{true\ score} + \sigma^2_{error}$, where

(2) $\sigma^2_{true\ score} = \sigma^2_{trait} + \sigma^2_{method}$, which implies that

(3) $\sigma^2_{total} = \sigma^2_{trait} + \sigma^2_{method} + \sigma^2_{error}$.

Analytical tools and critical cutoffs for statistics. The analyses for RQ1 were conducted with M*plus* 7 (Muthén & Muthén, 1998-2012). Full Information Maximum Likelihood (FIML) was used as the model estimation method. I used several techniques to measure the fit of single models to the data, including the model chi-square, maximum likelihood (ML)-based standardized root mean squared residual (SRMR), comparative fit index (CFI), and root mean square error of approximation (RMSEA), with the caution that RMSEA tends to overreject models with small sample sizes. Nonsignificant model chi-square would suggest that the exact-fit hypothesis is maintained and that the model is consistent with the covariance data. The SRMR measures the mean absolute covariance residual. A value of zero for the RMSEA and for the SRMR indicates a perfect fit. The CFI measures the relative improvement in the fit of the proposed model over that of a baseline model. A CFI score of 1 indicates perfect model fit. Based on Hu and Bentler (1999), the recommended cutoff criteria for acceptable model fit are SRMR = .08, RMSEA = .06, CFI = .96. The alpha level for the model coefficient estimates and related statistics was set at .05.

For the nested model comparisons, the main indices are the model chi-square and corresponding degrees of freedom; the former implies model fit to the data and the latter indicates the model parsimony. The two-tailed critical value of chi-square at an alpha level of .05 (e.g., $x^2 = 3.84$, $p = .05$) was used as the criteria for making decisions about two nested models being compared. For instance, given 1 degree of freedom fewer than the alternative model, if a model had a greater chi-square yet the difference was not more than 3.84, then this model would be retained and the alternative model would be rejected, for the retained model is more parsimonious and yet has a nonsignificantly different fit to the data.

The critical value for inter-factor correlations was set at > .80 (i.e., > 64% of shared variance) for two trait factors to be considered equivalent to one common factor. The cutoff was set at this high level because, in the MTMM models, the correlations between trait factors were true-score correlations without method-specific variance or error variance, which indicated the true level of association between two trait factors.

Exploring Students' Beliefs about Multiple Sources of Knowledge

RQ2a. Do students evaluate sources based on multiple source qualities? In order to answer this research question, I conducted an exploratory factor analysis (EFA) on the 14 sources in each of the 6 conditions (2 purposes × 3 topics). The purpose of the EFAs was to obtain a more parsimonious description of the sources in terms of common factors and relations between the factors (Fabrigar, Wegener, MacCallum, & Strahan, 1999). For each EFA, I used principal axis factoring with both Kaiser's criterion (Eigenvalue > 1; 1960) and parallel analysis (Horn, 1965) to decide the number of factors to retain. For multiple-factor solutions, a direct Oblimin factor rotation method was applied, hypothesizing that the extracted factors were to some degree correlated with each other.

To explore the sources from a slightly different perspective, I conducted nonmetric MDS with squared Euclidean distance to measure the relative proximity of the 14 sources. I examined the stress values and R^2 for the one-, two-, and three-dimension solutions for each MDS model. The cut-off of Stress was set at .08: any value greater than it would be considered a poor fit for the data (Beals, Krantz, & Tversky, 1968).

RQ2bcd. Differences in source beliefs in different conditions. Based on the MDS results, I computed source ratings by cluster for the two purposes in all three topic domains, and obtained a total of 18 scores (3 clusters × 2 purposes × 3 topics). Given that all scores were nested within individual students, I conducted a dependent-measures MANOVA to detect differences by cluster, by purpose, by topic, and by the interactions. For the significant effects, I examined the tests of within-subject contrast and accordingly compared estimated marginal means (with 95% confidence interval) by cluster, by purpose, by topic, or by the interaction to detect where the exact differences located.

Analytical tools and critical cutoffs for statistics. The analyses for RQ2 were conducted with SPSS Version 21.0 (IBM Corp., 2012). The alpha level for the model coefficient estimates and related test statistics was set at .05.

Relations between Epistemic Aims and Online Learning Outcomes

RQ3. Are epistemic aims and source beliefs associated with learning outcomes in the online research context? In order to find out the potential relations between epistemic aims, source beliefs and learning outcomes in the online research, I constructed a path model of online learning outcome based on the bivariate correlations between relevant variables, epistemic cognition theories (Chinn et al., 2011; Chinn, Rinehart, & Buckland, 2014), and the pilot study findings (Dai & Cromley, 2014, April). The model consisted of 3 sets of endogenous variables, including mastery goals, epistemic aims, source beliefs, learning outcome, and exogenous variables, including class membership, age, major, race, parent educational attainment, year in college, and perceived ability with sources. All variables were specified to predict learning outcome, and, additionally, epistemic aims, mastery goals, and source beliefs were specified to mediate the effects of some variables on learning outcome.

Analytical tools and critical cutoffs for statistics. The analyses for RQ4 were conducted with M*plus* 7.0 (Muthén & Muthén, 1998-2012). Full Information Maximum Likelihood (FIML) was used as the model estimation method. Based on Hu and Bentler (1999), the recommended cutoff criteria for acceptable model fit are SRMR = .08, RMSEA = .06, CFI = .96. The alpha level for the model coefficient estimates and related statistics was set at .05.

Power Analysis

Power analyses were conducted for the analytic approaches above to find out the minimum required sample size given an alpha level of .05 or lower and statistical power of .80 or greater. Considering the analyses for RQ1 have a higher demand for sample size I conducted two sets of power analysis for the analyses involved in this step. The rest of the analyses, including EFAs, chi square test, and path model, are either of an exploratory nature or of lower requirements for sample size, I did not perform power analyses for these analytic approaches.

Power analysis for the nested model comparisons of Models a-h was conducted based on MacCallum, Browne, and Cai (2006) with Stata syntax provided by Davey and Savla (2010). The key elements of the power analysis in MacCallum et al. (2006) are degrees of freedom (df) for the two models in comparison and the difference between the two df's. Results indicated that sample sizes of 100 to 500 would provide statistical power higher than .98 for this series of nested model comparisons (see Table 7).

Table 7

Power Analyses for Nested Model Comparisons and MTMM Model a

N	Nested model comparison	Model a (Fit index: RMSEA)		
	df_a vs. df_e (df_f or df_g) = 33 vs. 36	Not close fit (.05 - .10)	Close fit (.05 - .08)	Exact fit (.0 - .05)
100	.98	.67	.33	.24
200	.99	.96	.62	.54
300	~ 1	.99	.81	.79
400	~ 1	~1	.91	.91
500	~ 1	~1	.96	.97

Power analysis for the most complex model, the correlated-trait correlated-method model (Model a), was conducted, for it has the largest number of model parameters to estimate (i.e., fewest df). The analysis was conducted based on MacCallum, Browne, and Sugawara (1996) using Stata syntax by Davey and Savla

(2010). MacCallum et al. (1996) aimed to estimate sample sizes needed for a model to obtain exact fit (RMSEA = 0 ~ .05), close fit (RMSEA = .05 ~ .08), and not-close fit (RMSEA = .05 ~ .10). Model a has 45 parameters and 33 df; power analysis showed Model a needed a sample size of 130 to obtain a not-close fit, a sample size of 300 to obtain a close fit, and a sample size of 315 to obtain an exact fit. Therefore, I concluded that the minimal requirement of sample size needed for my dissertation study was 315.

CHAPTER 5. RESULTS

Descriptive Statistics

In this section I present item-level and subscale-level descriptive statistics for mastery goals, epistemic aims, source beliefs in the three domains of Antifreeze, Corrosion, and Heartburn, and for student perceived ability with sources. In addition, I present subscale-level descriptive statistics for learning outcome and prior achievement measures.

I screened for violation of normal distribution of item- and subscale-level scores. Normality of item and subscale scores was examined on two aspects of the distribution—skewness and kurtosis. Considering the main analyses in future steps involved confirmatory factor analysis and path analysis, based on Kline (2010) the cut-off values were set at 3.0 for skewness and 8.0 for kurtosis. In the present study, distributions that were non-normal were found to be either negative skewed (i.e., < -3.0), which indicates distributions censored above, or of a high positive kurtosis (i.e., > 8.0), which indicates that distributions have heavy tails and high peakedness, or both.

This section includes three parts of summary statistics: the first part is for epistemic aims and mastery goals, followed by the part on source beliefs (i.e., ratings on sources for developing and refuting beliefs) as well as perceived ability with sources. The last part is about online learning outcome and prior achievement.

Epistemic Aims and Mastery Goals

In brief, both item-level and subscale-level descriptive statistics showed that participants did set strong mastery goals and epistemic aims—true beliefs, justified beliefs, and explanatory connection—when conducting online research on the three chemistry topics. Comparatively, epistemic aims for justified beliefs and explanatory connection were founder to be weaker than mastery goals and epistemic aims for true beliefs. Detailed results are presented as follow:

Item-Level

Descriptive statistics at the item level for epistemic aims and mastery goals are presented in Table 22 (in Appendix D).

Normality. In the domains of Antifreeze and Corrosion, scores of Items 4 and 5 on true beliefs were not normally distributed—negatively skewed and highly peaked. In Heartburn, scores on all 6 items on true beliefs were not normally distributed—negatively skewed and highly peaked; scores on Item 4 on mastery goals were also of a high peakedness. All other item-level scores on epistemic aims and mastery goals were normally distributed.

Descriptive statistics. Within each domain, the epistemic aims items on true beliefs consistently have high scores (~ 90), followed by the mastery goals items (~ 85). Explanation connection and justified beliefs subscales each had an item on which the scores were medium (~ 60), with the rest items scoring at approximately 80. This pattern of item-level scores was found to be consistent in all three domains.

Subscale-Level

Descriptive statistics at the subscale[12] level for epistemic aims and mastery goals are presented in Table 8. In each topic domain, the fourth item of justified beliefs and the first two items of explanatory connection were reverse-coded to make scoring consistent with the rest of the items. The subscale scores were calculated by summing up the item

[12] Note that these subscales refer to those as designed in the questionnaire, e.g., the 6 items on epistemic aims for true beliefs in Antifreeze.

scores on each subscale (i.e. mastery goals, true beliefs, justified beliefs, and explanatory connection) and dividing the number of items (i.e., 8, 6, 6, and 6, respectively) within each topic domain (i.e., Antifreeze, Corrosion, and Heartburn). There were 4 subscales in each of the 3 domains, resulting in a total 12 subscales on the goals constructs.

Normality. True beliefs in the domains of Antifreeze and Heartburn were non-normally distributed with a high peakedness (greater than 8.0) and a negative skewness approaching -3.0. All other subscale scores on mastery goals and epistemic aims were normally distributed.

Descriptive statistics. In all three topic domains, students aimed very highly for true beliefs (M = 90 ~ 93), followed by the high levels of mastery goals (M = 83 ~ 86). Although students aimed for explanatory connection (M = 78 ~ 83) and justified beliefs (M = 75 ~ 77), these aims were not as strong as their aims for true beliefs or mastery goals.

Table 8

Subscale-Level Descriptive Statistics and Bivariate Correlation of Mastery Goals and Epistemic Aims in Three Topics

Subscale	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. A_Mas	354	0	100	83.88	18.55	-1.68	3.4	--											
2. C_Mas	354	0	100	82.52	19.95	-1.82	3.9	.704[b]	--										
3. H_Mas	354	4.4	100	85.85	16.97	-1.80	3.93	.739[b]	.691[b]	--									
4. A_Tru	354	0	100	90.97	15.19	-2.82	10.57	.542[b]	.457[b]	.437[b]	--								
5. C_Tru	354	5	100	90.32	14.21	-2.22	6.99	.430[b]	.424[b]	.393[b]	.702[b]	--							
6. H_Tru	354	5	100	92.65	12.59	-2.95	12.71	.396[b]	.352[b]	.457[b]	.732[b]	.724[b]	--						
7. A_Jus	354	1.7	100	75.72	18.8	-0.98	0.97	.584[b]	.508[b]	.452[b]	.540[b]	.467[b]	.426[b]	--					
8. C_Jus	354	0	100	74.6	19.16	-0.89	0.75	.519[b]	.517[b]	.449[b]	.407[b]	.466[b]	.366[b]	.717[b]	--				
9. H_Jus	354	0	100	76.97	17.82	-1.20	1.88	.487[b]	.478[b]	.511[b]	.395[b]	.370[b]	.413[b]	.758[b]	.680[b]	--			
10. A_Exp	354	0.83	100	79.48	17.97	-1.13	1.66	.576[b]	.468[b]	.457[b]	.505[b]	.403[b]	.368[b]	.619[b]	.546[b]	.508[b]	--		
11. C_Exp	354	0	100	78.41	17.42	-1.02	1.52	.526[b]	.558[b]	.447[b]	.420[b]	.456[b]	.337[b]	.595[b]	.633[b]	.481[b]	.700[b]	--	
12. H_Exp	354	0	100	83.18	16.16	-1.25	2.19	.499[b]	.452[b]	.525[b]	.472[b]	.392[b]	.478[b]	.549[b]	.475[b]	.614[b]	.695[b]	.612[b]	--

Note. [b] $p < .01$ (2-tailed). A = Antifreeze. C = Corrosion. H = Heartburn. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection.

Source Beliefs and Perceived Ability with Sources

In brief, both item-level and subscale-level summary statistics indicated that students perceived their ability with all 14 sources to be generally high, with the exceptions of understanding scholarly journals and scholarly discussion which were rated slightly lower. Second, students rated the 14 sources to be highly trustworthy for the purpose of believing information (referred to as “Trust-to-Believe” hereafter) on all three topics, whereas students rated these sources as moderately trustworthy for the purpose of refuting presented information (referred to as “Trust-to-Refute” hereafter). Detailed results are presented as follow:

Item-Level Statistics

Item-level descriptive statistics for student perceived ability with these sources are presented in Table 23 (Appendix D). Descriptive statistics for trustworthiness ratings of sources are presented in Table 24 (Appendix D).

Normality. Of the 14 items on the perceived ability with sources, students’ perceived abilities with professor’s post, classmate’s lab report, and online blog were non-normally distributed with a high peakedness (i.e., > 8.0) and a negative skewness approaching -3.0. Trust-to-Believe ratings of a professor’s post in Antifreeze and Corrosion were negatively skewed and highly peaked. In addition, Trust-to-Believe ratings of scholarly journal for Antifreeze and Trust-to-Believe ratings of a textbook for Corrosion both had high kurtosis. All other source ratings were normally distributed.

Descriptive statistics. Students rated their abilities with the 14 sources to be high, in which perceived abilities to understand chemistry journal articles and to understand online discussion by scholars and experts were rated lower by these students from this context than the rest of the sources, and the abilities to understand professor's posts on Blackboard, classmate's lab report, Wikipedia, and anonymous blogs were rated the highest by these students from this context.

Of the 14 sources, the highly-rated sources included a professor's post, scholarly journal, textbook, ER doctor, science museum website, and reference book. The low-rated sources included a classmate's lab report posted on the course Blackboard site, Wikipedia, and anonymous blog.

Subscale-Level Statistics

Subscale-level descriptive statistics for sources beliefs are presented in Table 9. The subscale scores of perceived ability with sources were calculated by summing up the ability ratings and dividing by the number of items (i.e., 14). The source-beliefs subscale scores were calculated by summing up the item-level ratings in each condition (i.e., Trust-to-Believe vs. Trust-to-Refute) and dividing by the number of items (i.e., 14), within each domain (i.e., Antifreeze, Corrosion, Heartburn). There were, therefore, a total of 6 subscale scores (2 purposes × 3 topics).

Table 9

Subscale-Level Descriptive Statistics and Bivariate Correlation for Source Beliefs

Subscale	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.
1. Pcvd	354	9.2	99.5	83.92	9.52	-2.07	10.86	--						
2. A_Bel	354	3.4	100	73.59	13.66	-0.91	1.75	$.138^{b}$	--					
3. C_Bel	354	3.1	100	74.58	13.47	-1.01	2.35	$.120^{a}$	$.793^{b}$	--				
4. H_Bel	354	3.9	100	73.65	13.66	-0.97	2.16	$.114^{a}$	$.789^{b}$	$.814^{b}$	--			
6. A_Ref	354	0	100	63.6	16.17	-0.71	0.75	$.141^{b}$	$.638^{b}$	$.570^{b}$	$.604^{b}$	--		
7. C_ Ref	354	0	99.6	62.51	16.28	-0.92	1.65	.074	$.591^{b}$	$.564^{b}$	$.583^{b}$	$.771^{b}$	--	
8. H_ Ref	354	0	100	63.13	16.92	-0.88	1.35	$.114^{a}$	$.566^{b}$	$.508^{b}$	$.569^{b}$	$.804^{b}$	$.740^{b}$	--

Note. ^{a} $p < .05$; ^{b} $p < .01$ (2-tailed). Pcvd = Perceived Ability with Sources. A = Antifreeze. C = Corrosion. H = Heartburn. Bel = Trust-to-Believe. Ref = Trust-to-Believe.

Normality. The subscale scores on perceived ability with sources had high kurtosis. Scores on all 6 subscales of source beliefs were normally distributed.

Descriptive statistics. Students reported generally high levels of perceived ability with the 14 sources (M = 83.9, SD = 9.5). They also rated the 14 sources to be generally trustworthy for them to believe the posts (Trust-to-Believe), and moderately trustworthy to refute presented information in the posts (Trust-to-Refute).

Online Learning Outcome and Prior Achievement

In a nutshell, students correctly answered less than half of the questions in the learning outcome measure. Also, due to the sources of participants—CHEM 1032 and CHEM 1031 classes, their prior achievement measures were different: about 11.3% of CHEM 1032 students obtained A and 17% obtained B to B^{+} from their prior CHEM 1031 course, whereas CHEM 1031 students on average scored 75% on Benchmark Exam I of the course. Detailed summary statistics are presented as follows:

Online Learning Outcome

Normality. The sum scores of 15 items on online learning outcome in three domains—Antifreeze, Corrosion, and Heartburn—were generally normally distributed. Subscale-level descriptive statistics for online learning outcome and prior achievement are presented in Table 10.

***Descriptive statistics*.** The mean was 6.8 (SD = 2.3), which indicates on average students correctly answered less than half of the items. CHEM 1032 students (M = 7.1, SD = 2.3) scored significantly higher on the learning outcome measure than CHEM 1031 students (M = 6.3, SD = 2.2; t[352] = 3.122, p = .002, d = 0.348). Class membership differentiated students' performance in the online learning outcome measure.

***Difference by class*.** CHEM 1031 and CHEM 1032 participants had significantly different scores on the online learning outcome measure. As expected, CHEM 1032 students scored significantly higher (M = 7.1, SD = 2.3) than CHEM 1031 students (M = 6.2, SD = 2.2; t[352] = 3.122, p = .002, d = .40). Class membership ought to be taken into account in analyses related to the online learning outcome.

Table 10

Descriptive Statistics of Learning Outcome and Course Achievement

	N	Min	Max	*M*	*SD*	Mdn	Skew	Kurt
Learning Outcome	354	0	13	6.8	2.3	7.0	-0.091	-0.274
CHEM 1032 Students	227	0	13	7.1	2.3	6	-0.018	-0.205
CHEM 1031 Students	127	0	11	6.2	2.2	7	-0.158	-0.240
CHEM 1032 Students								
CHEM 1031 Grade	210	1	9	6.0	2.2	6.0	-0.174	-1.074
CHEM 1031 Students								
Exam 1 Score	126	28	100	75.1	12.5	75.5	-0.467	0.846

Note. Min = Minimum. Max = Maximum. M = Mean. SD = Standard Deviation. Mdn = Median. Skew = Skewness. Kurt = Kurtosis.

Prior Achievement

Prior achievement in chemistry course. CHEM 1032 and CHEM 1031 students had different measures of prior achievement, due to the course sequence that CHEM 1031 was the first college-level chemistry course at the institution, and was a prerequisite for CHEM 1032. Therefore, for participants from CHEM 1032, the prior achievement measure was their CHEM 1031 grade, and for participants from CHEM 1031, the prior achievement measure was their scores on the first benchmark exam in the semester.

With 17 students not consenting to provide their CHEM 1031 grade or who had not taken this course at the institution due to transfer, a total of 210 prior grades in CHEM 1031 were gathered for participants from CHEM 1032. The grades were generally normally distributed. Forty students (11.3%) obtained an A, 25 students (7.1%)

obtained an A-, 27 students (7.6%) obtained a B+, 30 student (8.5%) obtained a B, and the same number of students obtained a B-. In addition, 23 students (7.3%) obtained a C, and 26 students earned a C-. After recoded from letter grades (D to A) to numeric values (1 to 9), I found the mean grade to be 6 (*SD* = 2.2), which was equivalent to a letter grade of B.

With 1 participant not taking Exam 1, a total of 126 exam grades were gathered for participants from CHEM 1031. Exam scores were generally normally distributed, with one low-scoring outlier. The mean exam score was 75.1 (*SD* = 12.5).

Correlations

To gain a preliminary understanding of relations amongst the constructs of goals, beliefs, prior achievement, and learning outcome, I calculated bivariate correlations on scores of mastery goals, epistemic aims, source beliefs, perceived ability with sources, prior achievement, and online learning outcome. In this section, I present 1) bivariate correlations among epistemic aims and mastery goals, 2) bivariate correlations among source beliefs and perceived ability with sources, and, finally, 3) bivariate correlations among all goals, source beliefs, perceived ability, prior achievement, and learning outcome variables.

Briefly, there were multiple significant bivariate correlations among most of the construct subscale scores, which supported further inquiries about relationships among goals, source beliefs, perceived ability, and learning outcome. Detailed results are presented in the following subsections.

Epistemic Aims and Mastery Goals

Pearson correlation coefficients of goals are presented in Table 8. In general, there were strong positive correlations among subscales of mastery goals and epistemic aims. All correlation coefficients were significant at the alpha level of $p < .01$, and ranged from .337 to .758. Within-construct subscale scores (e.g., mastery goals in Antifreeze, in Corrosion, and in Heartburn) correlated.60 to .75. Cross-construct subscale scores (e.g., mastery goals and true beliefs) correlated comparatively lower at approximately .35 to .60.

Source Beliefs and Perceived Ability with Sources

Pearson correlation coefficients of source beliefs and perceived ability are presented in Table 8. Perceived ability with sources was significantly correlated with all source beliefs except Trust-to-Refute in Corrosion. The significant correlations were all positive but small in magnitude (~.11).

Regarding the source beliefs subscales, Trust-to-Believe ratings were significantly positively correlated with each other at approximately .78 among the 3 topic domains. The same correlation pattern applied to Trust-to-Believe ratings among the 3 topic domains. Comparatively, the between-topic correlations (e.g., Trust-to-Believe in Antifreeze, Corrosion, and Heartburn; .740 ~ .814) were stronger than the between-purpose correlations (e.g., Trust-to-Believe vs. Trust-to-Refute on the topic of Antifreeze; .508 ~ .638).

Pearson correlations on item-level scores (Table 24 in Appendix D) showed a consistent pattern of small to medium positive bivariate correlations amongst the 14 source ratings for the two purposes (Trust-to-Believe and Trust-to-Refute) in the three domains (Antifreeze, Corrosion, and Heartburn), with a small number of nonsignificant correlations being the exception.. Regarding item-level bivariate correlations on perceived ability with the 14 sources (Table 23 in Appendix D), all correlations were significant and positive, with a magnitude of .225 to .817.

Prior Achievement and Online Learning Outcome

For participants from CHEM 1032, their prior achievement (i.e., grade) in CHEM 1031 was not found to be associated with online learning outcome on the three chemistry topics ($r[208] = .098$, $p = .156$). For those from CHEM 1031, however, their Exam 1 scores were significantly correlated with online learning outcome ($r[124] = 221$, $p = .018$).

Goals, Source Beliefs, Perceived Ability, Prior Achievement, and Online Learning Outcome

Between the variables of goals, source beliefs, perceived ability with sources, prior achievement, and online learning outcome, I found a number of statistically significant correlations (Table 11). Perceived ability was significantly positively correlated with all subscales on source beliefs, goals, prior achievement, and learning outcome (.11 ~ .33), except with source beliefs (Trust-to-Refute).

Most of the correlations between source beliefs and goals were significant positive correlations (.11 ~ .31). Specifically, all mastery-goals subscales and true-beliefs subscales were significantly positively correlated with source beliefs. Trust-to-Refute had more (i.e., 33 out of 36) significant correlations with goals than Trust-to-Believe (i.e., 25 out of 36).

Regarding correlations with the online learning outcome, perceived ability with sources was significantly positively associated all measure scores (.24 ~ .31), whereas source beliefs were not significantly correlated with online learning outcome scores or either of the prior achievement scores. Mastery goals for the Antifreeze topic was the only mastery goals measure that was significantly correlated with the learning outcome and prior achievement. Consistently, all three true-beliefs subscales were significantly positively correlated with the online learning outcome (.14 ~ .20), and all three explanatory-connection subscales were significantly positively correlated with the online learning outcome (.17 ~ .21), but none of the subscales on justified beliefs were significantly correlated with the online learning outcome.

In sum, the subscales *within* the same construct were consistently correlated with each other. Most of the correlations *between* goals, source beliefs, and perceived ability were significant. The online learning outcome was significantly correlated with all epistemic aims except the justified-beliefs subscales, however it was not significantly correlated with any source-beliefs subscales. Prior achievement measures were not correlated with any of the epistemic-aims or source-beliefs subscales.

Table 11

Bivariate Correlations of Mastery Goals, Epistemic Aims, Perceived Ability, Source Beliefs, Learning Outcome, and Achievement

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21a.	21b.
1. Pcvd	--																					
2. A_Bel	.138[b]	--																				
3. C_Bel	.120[a]	.793[b]	--																			
4. H_Bel	.114[a]	.789[b]	.814[b]	--																		
5. A_Ref	.141[b]	.638[b]	.570[b]	.604[b]	--																	
6. C_Ref	.074	.591[b]	.564[b]	.583[b]	.771[b]	--																
7. H_Ref	.114[a]	.566[b]	.508[b]	.569[b]	.804[b]	.740[b]	--															
8. A_Mas	.317[b]	.223[b]	.210[b]	.209[b]	.232[b]	.174[b]	.146[b]	--														
9. C_Mas	.278[b]	.161[b]	.175[b]	.175[b]	.181[b]	.120[a]	.114[a]	.704[b]	--													
10. H_Mas	.210[b]	.209[b]	.207[b]	.236[b]	.188[b]	.152[b]	.124[a]	.739[b]	.691[b]	--												
11. A_Tru	.334[b]	.298[b]	.236[b]	.245[b]	.216[b]	.175[b]	.233[b]	.542[b]	.457[b]	.437[b]	--											

Table 11, continued

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21a.	21b.
12. C_Tru	.326^{b}	.235^{b}	.259^{b}	.237^{b}	.241^{b}	.186^{b}	.204^{b}	.430^{b}	.424^{b}	.393^{b}	.702^{b}	--										
13. H_Tru	.261^{b}	.309^{b}	.263^{b}	.297^{b}	.257^{b}	.220^{b}	.245^{b}	.396^{b}	.352^{b}	.457^{b}	.732^{b}	.724^{b}	--									
14. A_Jus	.328^{b}	.114^{a}	.062	.092	.168^{b}	.140^{b}	.136^{a}	.584^{b}	.508^{b}	.452^{b}	.540^{b}	.467^{b}	.426^{b}	--								
15. C_Jus	.342^{b}	.112^{a}	.034	.106^{a}	.194^{b}	.210^{b}	.159^{b}	.519^{b}	.517^{b}	.449^{b}	.407^{b}	.466^{b}	.366^{b}	.717^{b}	--							
16. H_Jus	.270^{b}	.089	-.025	.014	.159^{b}	.117^{a}	.130^{a}	.487^{b}	.478^{b}	.511^{b}	.395^{b}	.370^{b}	.413^{b}	.758^{b}	.680^{b}	--						
17. A_Exp	.347^{b}	.108^{a}	.080	.117^{a}	.156^{b}	.110^{a}	.110^{a}	.576^{b}	.468^{b}	.457^{b}	.505^{b}	.403^{b}	.368^{b}	.619^{b}	.546^{b}	.508^{b}	--					
18. C_Exp	.404^{b}	.073	.067	.074	.118^{a}	.079	.037	.526^{b}	.558^{b}	.447^{b}	.420^{b}	.456^{b}	.337^{b}	.595^{b}	.633^{b}	.481^{b}	.700^{b}	--				
19. H_Exp	.280^{b}	.130^{a}	.073	.120^{a}	.130^{a}	.094	.095	.499^{b}	.452^{b}	.525^{b}	.472^{b}	.392^{b}	.478^{b}	.549^{b}	.475^{b}	.614^{b}	.695^{b}	.612^{b}	--			
20. LO	.311^{b}	.049	.095	.036	.056	.024	.025	.121^{a}	.071	.003	.199^{b}	.171^{b}	.137^{b}	.083	.029	.015	.205^{b}	.173^{b}	.193^{b}	--		
21a. Grade	.178^{b}	.037	-.010	-.006	.076	.062	-.028	.059	-.033	.025	.108	.083	.080	.066	.026	.047	.116	.144	.112^{a}	.098	--	
21b. Exam 1	.236^{b}	.105	.157	.125	.019	.061	.130	-.180^{a}	-.005	-.051	.100	.154	.128	-.078	-.008	.038	-.031	-.028	.079	.211^{a}	--	--

Note. ^{a} $p < .05$; ^{b} $p < .01$ (2-tailed). Pcvd = Perceived Ability with Sources. A = Antifreeze. C = Corrosion. H = Heartburn. Bel = Trust-to-Believe. Ref = Trust-to-Refute. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection. LO = Learning Outcome. Grade = CHEM 1032 students' prior grade in CHEM 1031. Exam 1 = CHEM 1031 students' scores on Exam 1.

Exploratory Factor Analysis

To gain a preliminary understanding about the factor structure of goals (i.e., mastery goals and epistemic aims) and source beliefs, I conducted exploratory factor analyses on (1) items on mastery goals and epistemic aims in each of the three domains, (2) source beliefs (Trust-to-Believe and Trust-to-Refute) in each of the three topic domains, and (3) perceived ability about the 14 sources.

Briefly, EFA results showed a clear 4-factor solution for items on mastery goals and epistemic aims—true beliefs, justified beliefs, and explanatory connection—in each topic domain. Items (except the fourth item on justified beliefs) were highly loaded on the intended factor, with minimal cross-loadings. The results primarily supports 4 separate constructs—mastery goals, true beliefs, justified beliefs, and explanatory connection—in each topic domain, and that the reliability of each subscale was good, which warranted further analyses of goals at the subscale-level.

Regarding the EFAs on source beliefs, results indicated that sources were differentiated between trustworthy (e.g., professor's post, experts in the field) vs. less trustworthy items (e.g., Wikipedia, "my" experiment). The same factor solution was consistently found in all three topic domains for both Trust-to-Believe and Trust-to-Refute. However, more item-level analysis was in need to understand the dimensionality of students' beliefs about sources, especially about the less-trustworthy sources.

An EFA on perceived abilities with the 14 sources indicated a unidimensional factor structure.

Detailed EFA results on goals, source beliefs, and perceived ability with sources are presented as follows:

Mastery Goals and Epistemic Aims

An exploratory factor analysis was conducted on the 26 items of mastery goals and epistemic aims in each topic domain using M*plus* 7.0 (Muthén & Muthén, 1998-2012). The extraction method was maximum likelihood estimation with robust standard errors (MLR) accounting for items with a negatively skewed score distribution. When necessary, Geomin Oblique was used as the rotation method to allow for the estimation of potential inter-factor covariance. Two methods of determining the number of factors were used, including Kaiser's criterion of Eigenvalue larger than 1.0 (Kaiser, 1960), and Horn's parallel analysis which suggests retaining all factors whose raw data Eigenvalue is greater than percentile random data Eigenvalue (Horn, 1965). The cutoff for high factor loadings was .30 after standardizing.

Both Kaiser's criterion and Horn's parallel analysis suggested 4 factors for the 26 mastery goals and epistemic aims in each topic domain with scores from all 354 participants. EFAs extracting 4 goals factors showed a factor structure consistently for all three topic domains: the majority of the items were highly loaded on the designed subscale factors. One exception was the fourth item on aims for justified beliefs, which did not load on any of the factors in any of the topic domain with a loading higher than .30. I eliminated this item from further analyses, and ran the EFA analyses again with reduced items.

Kaiser's criterion and Horn's parallel analysis again suggested 4 factors for the 25 mastery goals and epistemic aims with scores from all 354 participants. I conducted the EFA models extracting 4 goals factors (See Table 12 for item loadings), and found that the EFAs showed a factor structure consistently for all three topic domains: inter-factor correlations ranged from .55 to .70, and all items were highly loaded (above .30) on the designed subscale factors, with a small number of item cross-loadings. In general, items were consistently loaded on the designed goals factors in all three topic domains, which reflected the theoretical meanings of the items.

EFAs on the retained goals items provided supports for a multidimensional factor structure and good reliability for each subscale. For further analyses at the subscale level, I calculated the subscale scores by summing up item scores in a subscale and dividing the number of items.

Table 12

Standardized Item Loadings of Exploratory Factor Analyses on Goals in the Domains of Antifreeze, Corrosion, and Heartburn

Subscale	*Antifreeze*					*Corrosion*					*Heartburn*				
		Goals Factor					Goals Factors					Goals Factors			
	Item	Mast	Tru	Jus	Exp	Item	Mast	Tru	Jus	Exp	Item	Mast	Tru	Jus	Exp
Mastery	1.	**.613***				1.	**.757***				1.	**.621***			*.312**
Goals	2.	**.646***	*.336**			2.	**.811***				2.	**.622***			
	3.	**.975***				3.	**.859***				3.	**.913***			
	4.	**.445***	*.511**			4.	**.683***				4.	**.317***			
	5.	**.804***				5.	**.844***				5.	**.800***			
	6.	**.798***				6.	**.632***				6.	**.639***			
	7.	**.360***				7.	**.657***				7.	**.436***			
	8.	**.653***				8.	**.621***				8.	**.743***			

Table 12, continued

Subscale	*Antifreeze*					*Corrosion*					*Heartburn*				
		Goals Factor					Goals Factors					Goals Factors			
	Item	Mast	Tru	Jus	Exp	Item	Mast	Tru	Jus	Exp	Item	Mast	Tru	Jus	Exp
Aims for	1.		**.804***			1.		**.760***			1.		**.712***		
True Beliefs	2.		**.839***			2.		**.928***			2.		**.394***		*.339**
	3.		**.614***			3.		**.314***			3.		**.881***		
	4.		**.832***			4.		**.464***			4.		**.982***		
	5.		**.790***			5.		**.638***			5.		**.633***		
	6.		**.734***			6.		**.631***			6.		**.425***		
Aims for	1.		*.329**	**.596***		1.			**.320***		1.			**.421***	*.419**
Justified	2.			**.782***		2.			**.893***		2.			**.837***	
Beliefs	3.			**.721***		3.			**.814***		3.			**.696***	
	5.			**.676***		5.			**.836***		5.			**.887***	
	6.			**.672***		6.			**.776***		6.			**.892***	

Table 12, continued

Subscale	*Antifreeze*					*Corrosion*					*Heartburn*				
		Goals Factor					Goals Factors					Goals Factors			
	Item	Mast	Tru	Jus	Exp	Item	Mast	Tru	Jus	Exp	Item	Mast	Tru	Jus	Exp
Aims for	1.				**.304***	1.				**.486***	1.				**.416***
Explanatory	2.				**.441***	2.				**.296***	2.				**.386***
Connection	3.				**.681***	3.				**.596***	3.				**.610***
	4.				**.696***	4.				**.387***	4.				**.786***
	5.				**.858***	5.				**.901***	5.				**.856***
	6.				**.758***	6.				**.803***	6.				**.814***

Note. * $p < .05$. Boldface indicates items designed to load on a certain subscale factors. Italic indicates significant high cross-loadings. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection.

Perceived Ability and Source Beliefs

Exploratory factor analyses were conducted on 1) students' perceived ability with the 14 sources and 2) on 14 source ratings for each purpose (Trust-to-Believe and Trust-to-Refute) in each topic domain using M*plus* 7.0 (Muthén & Muthén, 1998-2012). The extraction method was maximum likelihood estimation with robust standard errors (MLR) accounting for items with a negatively skewed score distribution. When necessary, Geomin Oblique was used as the rotation method to allow for the estimation of potential inter-factor covariance. Two methods of determining the number of factors were used, including Kaiser's criterion of Eigenvalue larger than 1.0 (Kaiser, 1960), and Horn's parallel analysis which suggests retaining all factors whose raw data Eigenvalue is greater than percentile random data Eigenvalue (Horn, 1965). The cutoff for high factor loadings is .30 after standardizing.

Both Kaiser's criterion and Horn's parallel analysis suggested 1 factor for perceived ability with the 14 sources. The 1-factor EFA model on perceived ability with sources indicated high loadings (> .39) on the factor—perceived ability (See Table 13).

Table 13

Standardized Item Loadings for Perceived Ability and Trustworthiness Ratings for Sources

Sources	Perceived Ability	Trust-to-Believe						Trust-to-Refute					
		Antifreeze		Corrosion		Heartburn		Antifreeze		Corrosion		Heartburn	
		Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
1. Professor's post	.386*	.820*		.809*		.577*		.622*		.742*		.685*	
2. "My" experiment	.593*		.534*		.525*		.498*		.679*		.525*		.634*
3. Scholarly journal	.784*	.549*		.734*			.399*	.627*		.665*		.736*	
4. Scholar discussion	.754*	.418*			.493*		.636*	.525*		.503*		.385*	*.313**
5. Classmate's lab report	.638*		.751*		.696*		.522*		.752*		.681*		.839*
6. Documentary	.802*				.607*		.554*	.519*		.560*	*.352**	.480*	*.303**
7. Experiment video	.747*	.428*			.618*		.775*	.567*		.485*	*.354**	.473*	*.371**

Table 13, continued

Sources	Perceived Ability	Trust-to-Believe						Trust-to-Refute					
		Antifreeze		Corrosion		Heartburn		Antifreeze		Corrosion		Heartburn	
		Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
8. Textbook	.743*	.781*		.878*		.848*		.873*		.885*		.901*	
9. Expert in field	.625*	.599*		.566*			.498*	.626*		.689*		.653*	
10. Anonymous blog	.495*		.572*		.692*		.554*		.589*		.692*		.579*
11. Newspaper	.821*	.543*			.419*		.538*	.603*		.489*		.575*	
12. Wikipedia	.598*		.374*		.582*		.390*		.401*		.468*		.422*
13. Museum website	.820*	.636*		.733*		.491*		.755*		.756*		.826*	
14. Reference book	.800*	.775*		.831*		.997*		.901*		.870*		.833*	

Note. * $p < .05$. Item loadings lower than .300 are not shown in this table. Italics indicate significant item cross-loadings that are greater than .300.

Both Kaiser's criterion and Horn's parallel analysis suggested 2 factors for source ratings for each purpose in each topic domain. The 2-factor solution for the 14 sources showed a moderate-high inter-factor correlation (~ .60) and high item loadings with a small number of cross-loadings (See Table 13). However, some items were not consistently loaded on the same factor across topic domains and between the two purposes; in addition, there were a number of item cross-loadings for Trust-to-Refute ratings in Corrosion and Heartburn. The EFA results suggested the 14 sources manifested quite differently in students' online research across topics, and that they may not be consistently taken as equally trustworthy for believing vs. refuting presented information, even on the same topic. Further item-level analyses on source ratings were necessary in order to better understand students' conceptualization of these sources in the online research context.

Multitrait-Multimethod Analysis

In this section, I present results about goals—mastery goals and epistemic aims—in the three topic domains of *Antifreeze, Corrosion*, and *Heartburn*. The main purposes include validating epistemic aims for true beliefs, justified beliefs, and explanatory connection, examining the context specificity of epistemic aims with three different topics, and seeking evidence for reliability of context-specific epistemic aims measure. Specifically, I conducted a series of MTMM analyses and model comparisons to answer the following research questions about mastery goals and epistemic aims:

RQ1a. When conducting online research on chemistry topics, do college students set epistemic aims for true beliefs, justified beliefs, and explanatory connection, which distinguish from mastery goals?

RQ1b. Are students' epistemic aims specific to the chemistry topic on which they conduct online research?

RQ1c. What is the true-score reliability of the subscales on context-specific epistemic aims for true beliefs, justified beliefs, and explanatory connection?

In brief, the MTMM modeling results supported the construct convergent and discriminant validity of epistemic aims: students had 3 distinct but correlated epistemic aims—true beliefs, justified beliefs, explanatory connection, which were all distinguished from yet correlated with mastery goals. Second, the MTMM modeling results supported context specificity of epistemic aims: students' epistemic aims and mastery goals were specific to the three chemistry topics in the online research. Third, students' responses indicated high true-score subscale reliability for this context-specific measure of epistemic aims and mastery goals. Detailed results are presented as follows:

RQ1a. Validation of Epistemic Aims

I first built a baseline model (Model a; Figure 10), which hypothesized context-specific goals and aims, as suggested by Chinn et al. (2011). The baseline model is a 4-traits 3-methods CFA model, in which the manifest variables were 12 subscale scores on goals (See Table 25 in Appendix D for variance-covariance matrix), specifying 4 inter-correlated trait factors (i.e., mastery goals, epistemic aims for true beliefs, justified beliefs, and explanatory connection) and 3 inter-correlated method factors (i.e., Antifreeze, Corrosion, and Heartburn). Inter-factor correlations between traits and methods were set to be zero (0). The 4-traits 3-methods model (Model a) had an excellent fit to the data (x^2 [33] = 39.485, p = .203; RMSEA [90%CI] = .024 [<.001, .048]; CFI

= .998; SRMR = .022), which provided preliminary support for the context-specific mastery goals and epistemic aims.

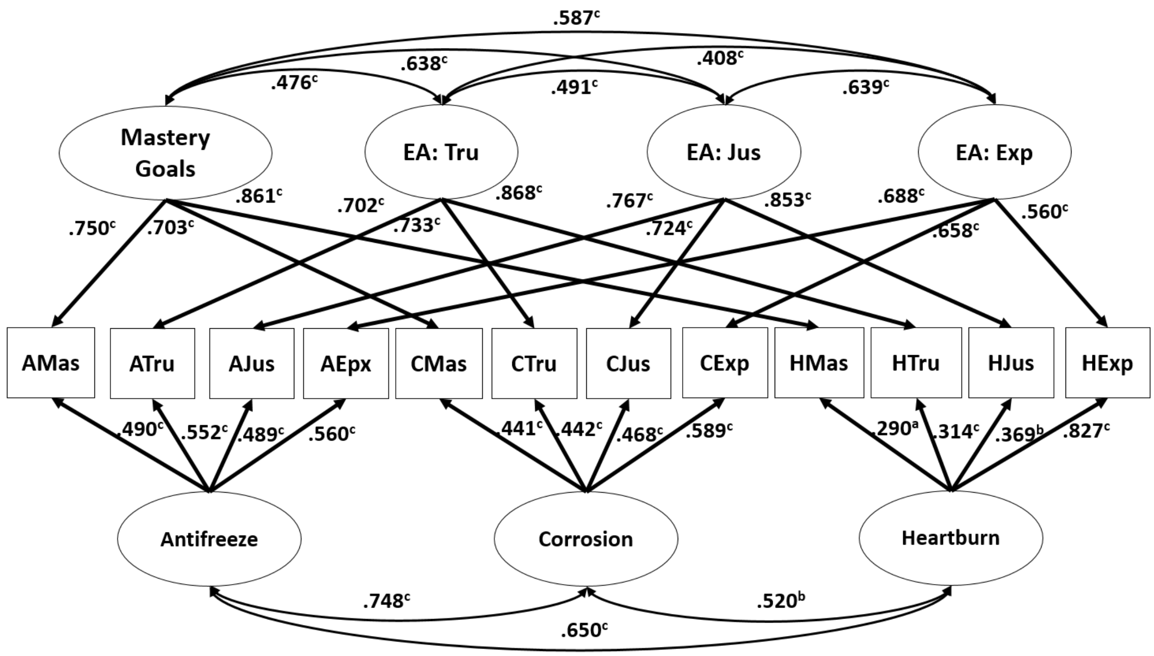


Figure 10. Model parameter estimates of the correlated-trait correlated-method model of a mastery-goals factor and three epistemic-aims factors—true beliefs, sufficiently justified beliefs, and explanatory connections in online research on three chemistry topics (Model a). Mas = Mastery Goals, EA = Epistemic Aims, Tru = True Beliefs, Jus = Justified Beliefs, Exp = Explanatory Connections. A = Antifreeze, C = Corrosion, and H = Heartburn. [a] $p < .05$. [b] $p < .01$. [c] $p < .001$.

To further assess the construct validity for epistemic aims, I sought evidence for the construct convergent validity and discriminant validity by comparing a series of alternative models to the baseline model (Model a) to validate the constructs of epistemic aims for true beliefs, justified beliefs, and explanatory connection. See Table 14 for model goodness-of-fit indices.

Table 14

Model Goodness-of-Fit Indices

Model	Model Description	*N*	Para.	x^2	*df*	*p*	Δx^2	Δdf	RMSEA (90% CI)	CFI	SRMR
A	**Traits: Mas, Tru, Jus, Exp; Methods: Antif, Corros, Heartb**	**354**	**57**	**39.485**	**33**	**.203**	**--**	**--**	**.024 (.000, .048)**	**.998**	**.022**
B	No trais; Methods: Antif, Corros, Heartb	354	39	940.272	51	<.001	898.310	18	.222 (.210, .234)	.716	.085
C	Trait: Goals; Methods: Antif, Corros, Heartb	354	51	535.494	39	<.001	493.532	6	0.190 (.176, .204)	.841	.056
D	Traits: Mas, EA; Methods: Antif, Corros, Heartb	354	52	309.149	38	<.001	267.187	5	.142 (.128, .157)	.913	.048
E	Traits: Mas, Jus, Exp; Methods: Antif, Corros, Heartb	354	54	62.532	36	.004	20.570	3	.046 (.026, .064)	.992	.040

Table14, continued

Model	Model Description	*N*	Para.	x^2	*df*	*p*	Δx^2	Δdf	RMSEA (90% CI)	CFI	SRMR
F	Traits: Mas, Tru, Exp;	354	54	66.223	36	.002	24.261	3	.049 (.030, .067)	.990	.039
	Methods: Antif, Corros, Heartb										
G	Traits: Mas, Tru, Jus;	354	54	55.128	36	.022	13.166	3	.039 (.015, .058)	.994	.025
	Methods: Antif, Corros, Heartb										
H	Traits: Mas, Tru, Jus, Exp;	354	54	126.493	36	<.001	84.531	3	.084 (.069, .100)	.971	.024
	Methods: Chem										

Note. Models b – h were compared to Model a (the baseline model). Boldface indicates the model that best fits the data. Para. = Number of parameters estimated in model. RMSEA = Root Mean Square Error of Approximation. CFI = Comparative Fit Index. SRMR = Standardized Root Mean Square Residual. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection. EA = Epistemic Aims. Antif = Antifreeze. Corros = Corrosion. Heartb = Heartburn.

Construct Convergent Validity

For convergent validity, I modeled the 12 subscale scores specifying the 3 inter-correlated method factors without any trait factors (Model b; Figure 11). Model b hypothesized that there were no variances in the subscale scores contributed by goals of any sort, in addition to the 3 method factors.

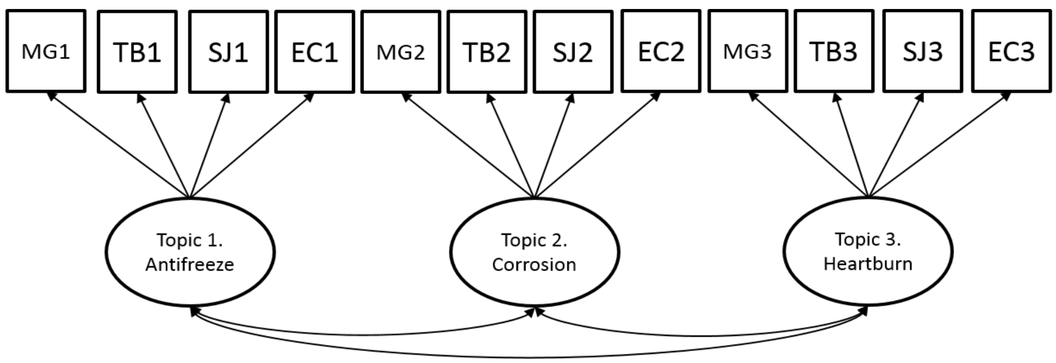


Figure 11. No-trait correlated-method model without aims/goals factors (Model b). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model b fit the data poorly (x^2 [51] = 940.272, p < .001; RMSEA [90%CI] = .222 [.210, .234]; CFI = .716; SRMR = .085). Model b, although more parsimonious, fit the data significantly worse than Model a (Δx^2 [Δ18] = 898.310, p < .05), which suggested that the trait factors were salient and provides evidence for construct convergent validity for goals (i.e., mastery goals and epistemic aims).

Construct Discriminant Validity

For discriminant validity, there were a total of 6 model comparisons between the baseline model and alternative models.

Model a vs. Model c (1-Trait 3-Methods Model). I first assessed whether there was one general goals factor instead of 4 goals factors—mastery goals, epistemic aims for truth beliefs, justified beliefs, and explanatory connection. I modeled the 12 subscale scores specifying 3 freely-correlated method factors and 1 trait factor. This model (Model c; see Figure 12) hypothesized that there was only 1 general goal factor that contributed to variances in the subscale scores in addition to the 3 method factors. The trait factor—general goals—was specified by setting the 4 trait factors to be perfectly correlated with each other. I also set the correlations between the trait factor and the method factors to be zero.

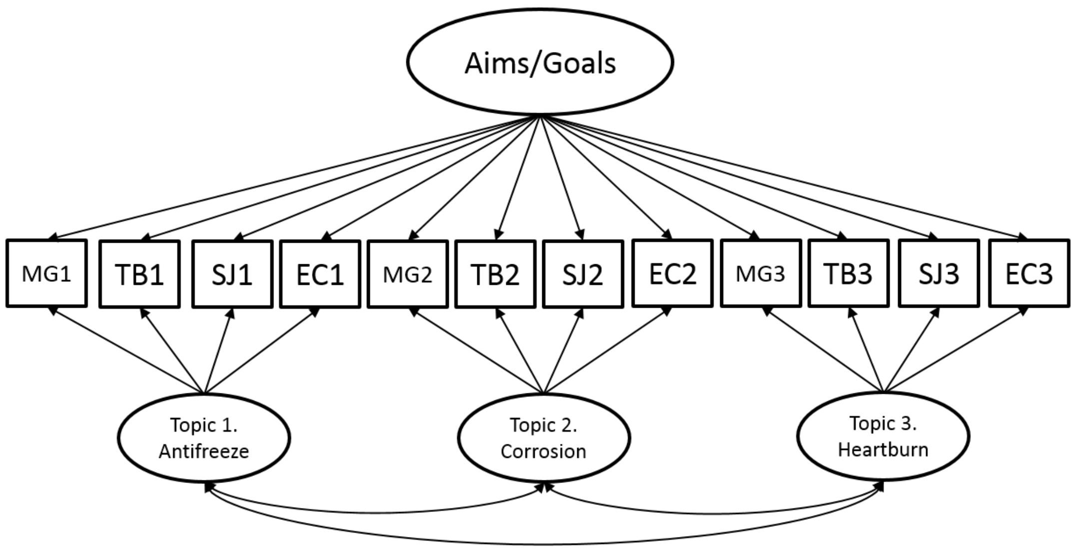


Figure 12. One-trait correlated-method model of a general aims/goals factor (Model c). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model c fit the data poorly (x^2 [39] = 535.494, $p < .001$; RMSEA [90%CI] = .190 [.176, .204]; CFI = .841; SRMR = .056). Model c, although more parsimonious, fit the data significantly worse than Model a (Δx^2 [Δ6] = 493.532, $p < .05$), which suggested that there were more one goals factor, and provides preliminary evidence for discriminant validity for the goals constructs. Model a, therefore, was retained for further model comparisons.

Model a vs. Model d (2-Traits 3-Methods Model). An important research aim for the study was to assess whether epistemic aims could be distinguished from mastery goals. Based on the findings about multiple goals/aims in the previous step, I assessed whether the factor of general epistemic aims could be distinguished from mastery goals. I modeled the 12 subscale scores specifying 3 freely-correlated method factors and 2 trait factors. This model (Model d; see Figure 13) hypothesized that there were only 2 goal factors—a mastery-goal construct and 1 general epistemic-aim construct—that contributed to variances in the subscale scores in addition to the 3 method factors. A trait factor—general epistemic aims—was specified by setting true beliefs, justified beliefs, and explanatory connection to be perfectly correlated with each other. The other trait factor was mastery goals. The two trait factors were set to be freely correlated, whereas the correlations between the trait- and method-factors were set to be zero.

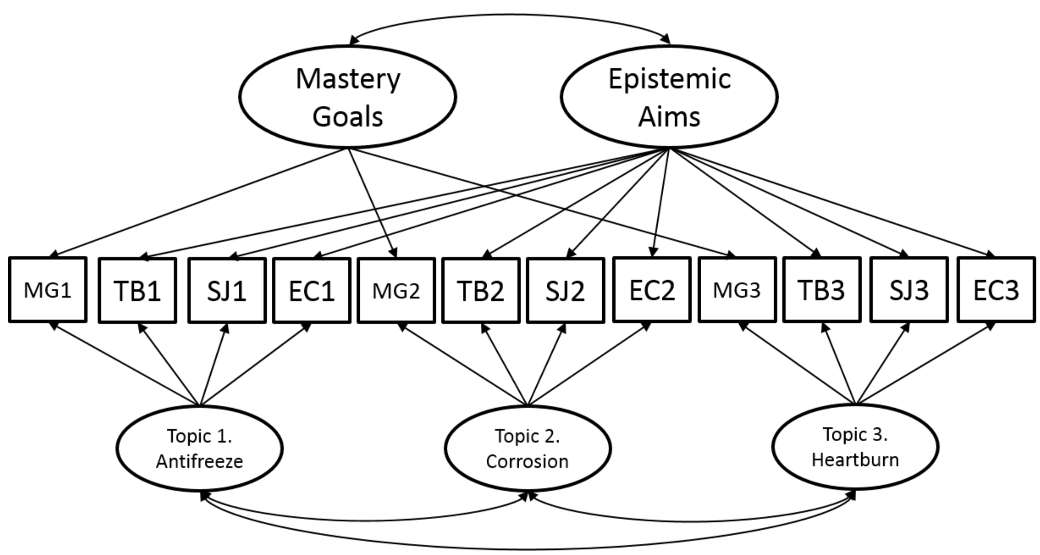


Figure 13. Two-trait correlated-method model of a mastery-goals factor and a general epistemic-aims factor (Model d). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model d fit the data poorly (x^2 [38] = 309.149, p < .001; RMSEA [90%CI] = .142 [.128, .157]; CFI = .913; SRMR = .048). Model d, although more parsimonious, fit the data significantly worse than Model a (Δx^2 [$\Delta 5$] = 267.187, p < .05), which suggested that epistemic aims were distinguishable from mastery goals and provides further evidence for discriminant validity of epistemic aims. Thus, Model a was retained.

Model a vs. Model e (3-Traits 3-Methods Model). Based on findings about distinguishable epistemic aims from mastery goals, I assessed whether three types of epistemic aims could be distinguished from mastery goals. First, I tested whether aims for true beliefs may be differentiated from mastery goals. I modeled the 12 subscale scores specifying 3 freely-correlated method factors and 3 trait factors. This model (Model e; Figure 14) hypothesized that there were 2 epistemic aims (justified beliefs and explanatory connection) and 1 mastery-goal factor (but no such goal as true beliefs) that contributed to variances in subscale scores in addition to the 3 method factors. A trait factor—mastery goals and true beliefs combined—was specified by setting true beliefs and mastery goals to be perfectly correlated with each other. The other two were aims for justified beliefs and aims for explanatory connection. The three trait factors were freely correlated, whereas correlations between the trait- and method-factors were set to be zero.

Model e fit the data inadequately (x^2 [36] = 62.532, p = .004; RMSEA [90%CI] = .046 [.026, .064]; CFI = .992; SRMR = .040). Model e, although more parsimonious, fit the data significantly worse than Model a (Δx^2 [$\Delta 3$] =20.570, p < .05), suggesting that epistemic aims for true beliefs were distinguishable from mastery goals and providing further evidence for discriminant validity of epistemic aims for true beliefs. Model a, therefore, was retained for further model comparisons.

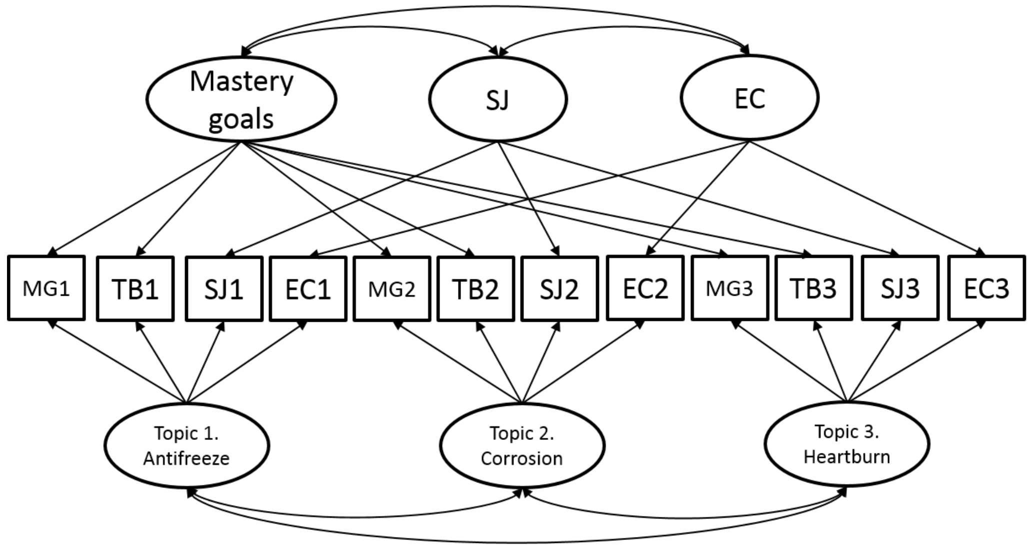


Figure 14. Three-trait correlated-method model of a mastery-goals factor, a sufficiently-justified-beliefs factor, and an explanatory-connections factor (Model e). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model a vs. Model f (3-Traits 3-Methods Model). I tested whether aims for justified beliefs may be differentiated from mastery goals. I modeled the 12 subscale scores by specifying 3 freely-correlated method factors and 3 trait factors. This model (Model f; Figure 15) hypothesized 2 epistemic aims (true beliefs and explanatory connection) and 1 mastery-goal factor (but no such goal as justified beliefs) contributing to variance in subscale scores in addition to the 3 method factors. A trait factor—mastery goals and justified beliefs combined—was specified by setting justified beliefs and mastery goals to be perfectly correlated. The three trait factors were set to be freely correlated; correlations between the trait- and method-factors were set to be zero.

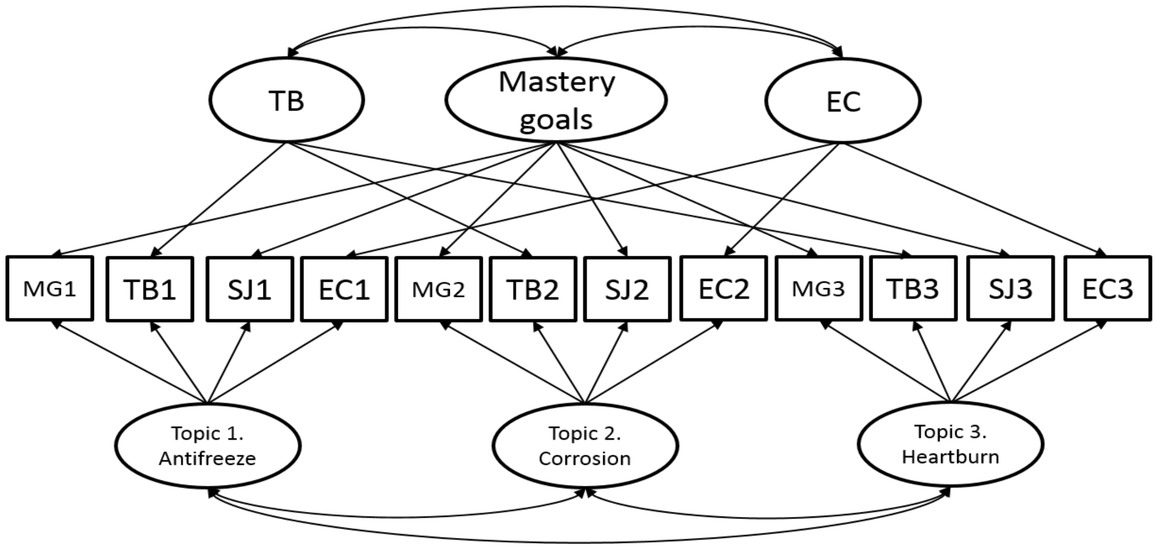


Figure 15. Three-trait correlated-method model of a mastery-goals factor, a true-beliefs factor, and an explanatory-connections factor (Model f). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model f fit the data inadequately (x^2 [36] = 66.223, p = .002; RMSEA [90%CI] = .049 [.030, .067]; CFI = .990; SRMR = .039). Model f, although more parsimonious, fit the data significantly worse than Model a (Δx^2 [Δ3] =24.261, $p < .05$), suggesting that epistemic aims for justified beliefs were distinguishable from mastery goals and providing further evidence for discriminant validity of epistemic aims for justified beliefs. Model a, therefore, was retained for further model comparisons.

Model a vs. Model g (3-Traits 3-Methods Model). I tested whether aims for explanatory connection could be differentiated from mastery goals. I modeled the 12 subscale scores by specifying 3 freely-correlated method factors and 3 trait factors. This model (Model g; Figure 16) hypothesized 2 epistemic aims (true beliefs and justified beliefs) and 1 mastery-goal factor (but no such goal as explanatory connection) contributing to subscale-score variance in addition to the 3 method factors. A trait factor—mastery goals and explanatory connection combined—was specified by setting explanatory connection and mastery goals to be perfectly correlated. The traits were set to be freely correlated; correlations between trait- and method-factors were set to be zero.

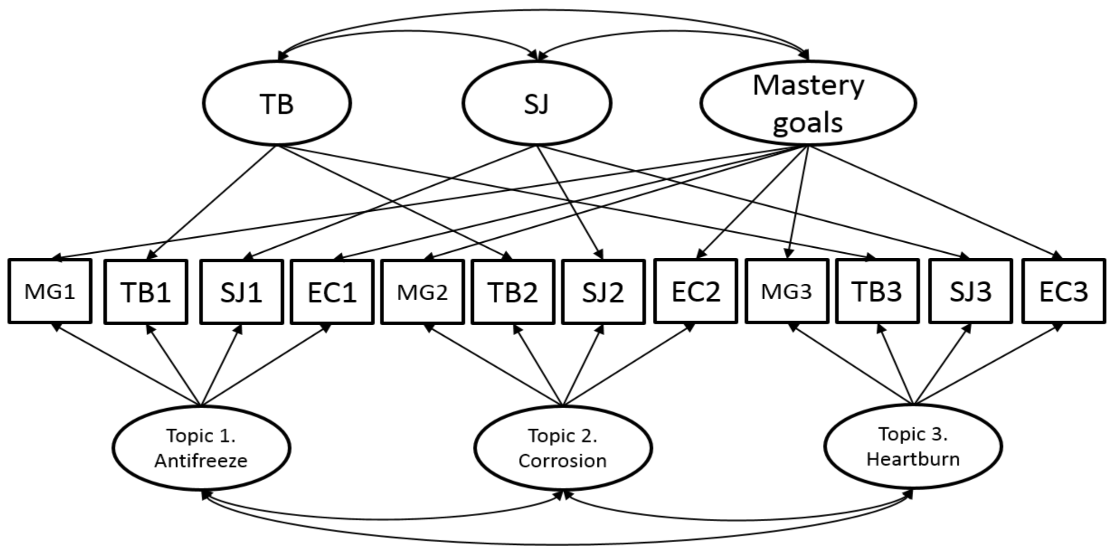


Figure 16. Three-trait correlated-method model of a mastery-goals factor, a true-beliefs factor, and a sufficiently-justified-beliefs factor (Model g). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model g fit the data inadequately (x^2 [36] = 55.128, p = .022; RMSEA [90%CI] = .039 [.015, .058]; CFI = .994; SRMR = .025). Model g, although more parsimonious, fit the data significantly worse than Model a (Δx^2 [Δdf] = 13.166 [3], $p < .05$), which suggested that epistemic aims for explanatory connection were distinguishable from mastery goals and provides further evidence for discriminant validity of epistemic aims for explanatory connection. Model a, therefore, was retained as the final model in the series of model comparison to test construct discriminant validity. The results support construct discriminant validity for epistemic aims for true beliefs, justified beliefs, and explanatory connection as three constructs that are all distinguishable from mastery goals.

Summary of Results

The testing and comparison of a series of MTMM models (Model a vs. Models b – g) provided evidence for construct convergent and discriminant validity for epistemic aims for true beliefs, justified beliefs, and explanatory connection. Specifically, the excellent fit of Model a, which specified 4 correlated trait factors—mastery goals, true beliefs, justified beliefs, and explanatory connection, provided preliminary evidence for construct validity. Further, Model a was compared to Model b and found to be a better-fitting model, suggesting evidence for construct convergent validity. Model a was then compared to Model c and found to be a better-fitting model, suggesting evidence for construct discriminant validity. Finally, Model a was compared to Models d – f and found to be a better-fitting model, which supported the hypothesis that epistemic aims for true beliefs, justified beliefs, and explanatory connection were different constructs from mastery goals.

As the retained model with excellent goodness-of-fit indices, Model a also showed high loadings on the trait factors (Table 15), which suggested good subscale reliability, and medium inter-factor correlations between the 4 trait factors, which indicated although mastery goals and the three epistemic aims were correlated they were different constructs that had large portions of variance unaccounted for by one another.

The MTMM analysis results showed that epistemic aims for true beliefs, justified beliefs, and explanatory connection were of construct convergent and discriminant validity, and were distinguishable from the construct—mastery goals.

Table 15

Parameter Estimates of MTMM Model (Model a)

	Trait (Construct)				Method (Topic Domain)		
	1. Mas	2. Tru	3. Jus	4. Exp	5. Antifreeze	6. Corrosion	7. Heartburn
Interfactor Correlation							
1.	--						
2.	.476[c]	--					
3.	.638[c]	.491[c]	--				
4.	.587[c]	.408[b]	.639[c]	--			
5.	0	0	0	0	--		
6.	0	0	0	0	.748[c]	--	
7.	0	0	0	0	.650[c]	.520[b]	--
Factor Loading							
A_Mas	.750[c]				.490[c]		

Table 15, continued

	Trait (Construct)				Method (Topic Domain)		
	1. Mas	2. Tru	3. Jus	4. Exp	5. Antifreeze	6. Corrosion	7. Heartburn
C_Mas	.703[c]					.441[c]	
H_Mas	.861[c]						.290[a]
A_Tru		.702[c]			.552[c]		
C_Tru		.733[c]				.442[c]	
H_Tru		.868[c]					.314[a]
A_Jus			.767[c]		.489[c]		
C_Jus			.724[c]			.468[c]	
H_Jus			.853[c]				.369[b]
A_Exp				.688[c]	.560[c]		
C_Exp				.658[c]		.589[c]	
H_Exp				.560[b]			.827[c]

Note. [a] $p < .05$. [b] $p < .01$. [c] $p < .001$. A = Antifreeze. C = Corrosion. H = Heartburn. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection.

RQ1b. Context Specificity of Epistemic Aims

I assessed context specificity of epistemic aims by comparing Model a to a 4-trait 1-method model (Model h; Figure 17). In Model h, I specified one method factor—chemistry—instead of 3 method factors of *Antifreeze*, *Corrosion*, and *Heartburn*.

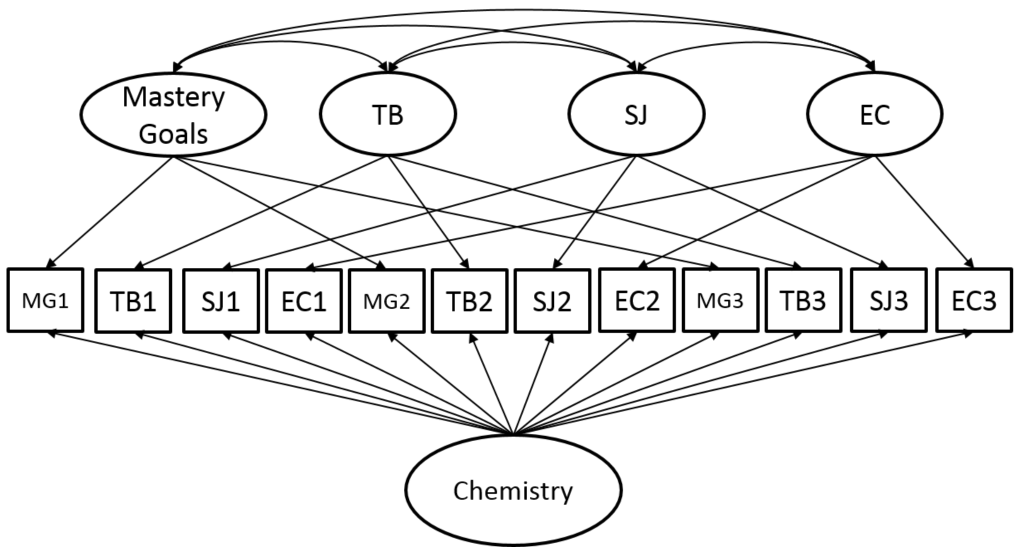


Figure 17. Correlated-trait one-method model of a mastery-goals factor and three epistemic-aims factors in online research on three chemistry topics (Model h). MG = Mastery Goals, TB = True Beliefs, SJ = Sufficient Justified Beliefs, EC = Explanatory Connection.

Model h fit the data poorly (x^2 [36] = 126.493, $p < .001$; RMSEA [90%CI] = .084 [.069, .100]; CFI = .971; SRMR = .024). Model h, although more parsimonious, fit the data significantly worse compared to Model a (Δx^2 [$\Delta 3$] = 84.531, $p < .05$). Model a, therefore, was retained. Results suggested that there were three different topics, rather than one general chemistry subject domain, that accounted for variances in students' responses to the items on mastery goals and epistemic aims.

In Model a, loadings on the method factors were all significant and higher than .30 (with an exception of .290). The inter-factor correlations between method factors were all significant and ranging from .520 to .748 (i.e., R^2 = .27 ~ .56), which suggests that the three topics were to a large extent correlated but at least half of the variance was unaccounted for by each other.

In sum, the MTMM model comparison results support the context specificity of epistemic aims for true beliefs, justified beliefs, and explanatory connection. The context specificity manifested in three different topic domains in the present study.

RQ1c. Subscale Reliability of Context-Specific Epistemic Aims

As the retained model in the MTMM model comparisons, the 4-trait 3-method model (Model a) hypothesized four distinct psychological construct (i.e., traits)—mastery goals, epistemic aims for true beliefs, justified beliefs, and explanatory connection—that were correlated with each other, and three topics (i.e., methods)—Antifreeze, Corrosion, and Heartburn—that were different but correlated with each other. All seven latent factors were hypothesized to account for variances in scores on the twelve subscales, in addition to residual variance (See Table 15 for parameter estimates)

Subscale reliability. Based on parameter estimates of the MTMM Model a, I decomposed variance in the twelve subscale scores into 1) measurement error, 2) variance contributed by trait (i.e., trait consistency), and 3) method-related variance (i.e., method specificity), in order to better understand the subscale reliability of the context-specific measure of epistemic aims.

Subscale score variance decomposition results are presented in Table 16. The subscale true-score reliability was the sum of trait-specific variances (by goals) and method-specific variances (by topics) based on Equation 2. As shown in Table 16, epistemic-aims subscales had adequate true-score reliability (> .74), and mastery-goals subscales had acceptable reliability (> .69). These results provided evidence for test reliability in addition to internal consistency.

Table 16

Variance Decomposition Based on MTMM Model (Model a)

Subscale	Total Variance		True-Score Variance	
	Proportion of Error Variances	True-Score Reliability	Trait Consistency	Method Specificity
A_Mas	.21	.79	.70	.30
C_Mas	.31	.69	.72	.28
H_Mas	.17	.83	.90	.10
A_Tru	.22	.78	.62	.38
C_Tru	.26	.74	.73	.27
H_Tru	.13	.87	.88	.12
A_Jus	.18	.82	.71	.29
C_Jus	.25	.75	.71	.29
H_Jus	.15	.85	.84	.16
A_Exp	.22	.78	.60	.40
C_Exp	.23	.77	.56	.44
H_Exp	.14	.86	.35	.77

Note. A = Antifreeze. C = Corrosion. H = Heartburn. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection.

Trait consistency and method specificity. Trait consistency was the amount of variance due to the goal factors divided by true-score variance. It appeared that all subscales (except *explanatory connection in Heartburn*) were of high trait consistency (> 50%). Although all explanatory connection subscales had relatively lower trait consistency. In general, although method specificity was lower compared to trait consistency, all subscale scores (except *mastery goals* and *true beliefs* in Heartburn) had considerable amounts of variance contributed by methods (> 15%).

Further evidence for validity. In addition to subscale reliability, parameter estimates of Model a also provided further evidence for construct validity and context specificity. Inter-factor correlations between mastery goals and the 3 types of epistemic aims were all significant (.408 ~ .639), suggesting small-medium shared variance between traits. Specifically, mastery goals and epistemic aims for justified beliefs had the highest correlation (r = .638, p < .001), indicating about 60% of variance of mastery goals unaccounted for by epistemic aims for justified beliefs, and vice versa. In addition, the inter-factor correlations between the three epistemic aims were also found to be at a medium level (.408 ~ .639), suggesting small to medium shared variance. Justified beliefs and explanatory connection had the highest correlation (r = .639, p < .001), which indicated about 60% of variance mastery justified beliefs unaccounted for by explanatory connection, and vice versa. The small-medium inter-factor correlations between mastery goals and epistemic aims provide further support for discriminant validity of epistemic aims.

Inter-factor correlations between the three topic domains were all significant (.520 ~ .748), suggesting medium shared variance between methods. Antifreeze and Corrosion were correlated at the highest level among the three (r = .748, p < .001), indicating about half of variance in Antifreeze unaccounted for by Corrosion, and vice versa. The medium inter-factor correlations amongst the three topic domains provide support for the context specificity of epistemic aims.

In sum, parameter estimates of Model a (the retained mode) indicated high true-score reliability for the measure of context-specific epistemic aims and mastery goals: the true-score variances were composed by considerable trait-related variances (epistemic aims and mastery goals) as well as method-related variances (three topics). It is evident in Model a that epistemic aims for true beliefs, justified beliefs, explanatory connection, and mastery goals were distinct constructs, and that students set these goals specific to the three different topics on which they conducted online research.

Multidimensional Scaling

In this section, I present results about beliefs about sources—students' ratings of sources in trustworthiness. The main purpose was to explore perceptual dimensions of beliefs about the 14 sources. Specifically, I conducted a series of multidimensional scaling (MDS) analyses to answer the following research question:

RQ2a. Do students evaluate sources based on multiple qualities when conducting online research on chemistry topics?

Briefly, MDS results indicated that students did evaluate how trustworthy the 14 sources were based on at least 2 dimensions—*professional expertise* and *first-hand knowledge*. Along these two dimensions, the 14 sources formed 3 clusters of sources, which were perceived as different by the students for their online research. The dimensions and clustering of sources were consistently found in all 6 conditions (Trust-to-Believe vs. Trust-to-Refute in three topic domains). Detailed results are as follows:

RQ2a. Perceptual Dimensions of Sources

Exploratory factor analysis results on the 14 sources provided preliminary evidence for multidimensionality of beliefs about sources. To further understand dimensionality of these source beliefs, I conducted nonmetric MDS with squared Euclidean distance as the measure of relative proximity of the 14 sources.

I examined the stress values and R^2 for the one-, two-, and three-dimension solutions for each MDS model. The one-dimension solution did not consistently indicate a good fit to the data (i.e., Stress ≥ .08), but both 2- and 3-dimension solutions fit the date excellently (see Table 17). The 3-dimension solution did not significantly outperform the 2-dimension solution in terms of goodness-of-fit.

Table 17

Stress and R^2 of MDS Models of Source Ratings

Topic	Purpose	# of Dimension(s)	Kruskal's Stress	R^2
Antifreeze	To Believe	3	0.04	1.00
		2	0.04	1.00
		1	0.09	.98
	To Refute	3	0.04	1.00
		2	0.05	.99
		1	0.08	.98
Corrosion	To Believe	3	0.03	1.00

Table 17, continued

Topic	Purpose	# of Dimension(s)	Kruskal's Stress	R^2
		2	0.04	1.00
		1	0.10	.98
	To Refute	3	0.04	.99
		2	0.05	.99
		1	0.08	.98
Heartburn	To Believe	3	0.04	1.00
		2	0.05	.99
		1	0.07	.99
	To Refute	3	0.04	.99
		2	0.05	.99
		1	0.08	.99

I then examined the maximum and minimum coordinates of sources (Table 18) on each dimension in both 2-dimension and 3-dimension solutions. I found that overall the 2-dimension solution yielded theoretically interpretable dimensions for the 14 sources, whereas the 3-dimension solution did not. The 2-dimensional solution consistently fit the source ratings in all 6 conditions (2 purposes × 3 topic domains). This result suggested that when students rated the 14 sources, they considered—explicitly or implicitly—two qualities of the sources (i.e., two dimensions of source beliefs).

Specifically, on the first dimension, sources on the positive end included a professor’s post on Blackboard, textbook, scholarly journal, and chemistry reference book, whereas on the negative end of the first dimension, representative sources included an anonymous blog, classmate's lab report, Wikipedia, and "my" experiment. The first dimension is interpreted to represent *professional expertise*. Sources located in between the two ends also complied the continuum of professional expertise.

Regarding the second dimension, sources on the positive end included "my" experiment, a classmate's lab report, and video of experiments, whereas on the negative end of the second dimension, representative sources included Wikipedia, a Newspaper, and a museum website. The second dimension is interpreted to represent *closeness to first-hand knowledge*. Sources located in between the two ends also complied with the continuum of closeness to first-hand knowledge.

The Euclidean distance 2-dimensional models showed similar patterns of relative proximities in all 6 conditions (Trust-to-Believe vs. Trust-to-Refute in three topic domains). The consistency of results indicated a stable 2-dimensional solution according to the students' ratings of 14 online sources: Students considered—explicitly or implicitly—both the level of professional expertise and closeness to first-hand knowledge as two critical qualities when they rated how trustworthy the sources were in their online research.

Table 18

Coordinates of 14 Sources for Developing Beliefs and Refuting Beliefs Scaled on 2 Dimensions in 3 Topic Domains

Source	Trust-to-Believe						Trust-to-Refute					
	Antifreeze		Corrosion		Heartburn		Antifreeze		Corrosion		Heartburn	
	PE	FHK	PE	FHK	PE	FHK	PE	FHK	PE	FHK	PE	FHK
1. Professor's post	**1.25**	-0.10	**1.33**	-0.06	**1.27**	0.11	**1.13**	**0.47**	**1.28**	**0.25**	**1.07**	**0.38**
2. "My" experiment	0.11	**0.86**	0.20	**0.97**	-0.09	**0.88**	***-1.13***	**0.61**	*-1.00*	**0.82**	***-0.94***	**0.58**
3. Scholarly journal	**1.16**	0.14	**1.17**	-0.02	**1.25**	0.03	**1.27**	-0.04	**1.29**	0.05	**1.24**	0.09
4. Scholars' discussion	0.45	0.23	0.53	-0.01	0.56	-0.32	0.53	-0.16	0.64	**0.45**	0.65	**0.33**
5. Classmate's lab report	*-2.01*	**0.69**	***-1.92***	**0.69**	***-2.16***	**0.69**	***-2.32***	**0.45**	***-2.34***	**0.55**	***-2.37***	**0.36**
6. Documentary	0.27	-0.10	0.03	-0.12	0.36	0.16	0.22	0.32	0.01	-0.18	0.21	0.27
7. Experiment video	0.46	**0.28**	0.40	**0.21**	0.37	**0.28**	0.25	**0.38**	0.12	-0.02	0.32	0.20
8. Textbook	**1.18**	0.09	**1.16**	0.03	**1.22**	0.04	**1.45**	0.06	**1.40**	0.02	**1.35**	0.04
9. Expert in field	**0.90**	-0.18	0.77	0.07	0.53	-0.06	0.88	-0.12	0.87	-0.24	0.76	-0.22

Table 18, continued

Source	Trust-to-Believe						Trust-to-Refute					
	Antifreeze		Corrosion		Heartburn		Antifreeze		Corrosion		Heartburn	
	PE	FHK	PE	FHK	PE	FHK	PE	FHK	PE	FHK	PE	FHK
10. Anonymous blog	*-3.39*	-0.15	***-3.41***	0.01	***-3.37***	-0.23	***-2.91***	***-0.46***	***-2.86***	***-0.29***	***-2.92***	***-0.37***
11. Newspaper	-0.81	***-0.48***	-0.78	***-0.34***	***-0.78***	***-0.37***	-0.83	***-0.39***	-0.76	***-0.44***	-0.61	***-0.33***
12. Wikipedia	*-1.71*	***-0.80***	***-1.68***	***-0.91***	***-1.58***	***-0.67***	***-1.51***	***-0.79***	***-1.55***	***-0.57***	***-1.69***	***-0.78***
13. Museum website	0.73	***-0.29***	0.88	***-0.26***	0.80	***-0.37***	0.91	***-0.18***	0.94	***-0.32***	0.91	***-0.24***
14. Reference book	**0.91**	-0.19	0.91	-0.25	**1.02**	-0.17	**1.21**	-0.15	**1.27**	-0.09	**1.30**	***-0.33***

Note. PE = Professional Expertise. FHK = First-Hand Knowledge. The three highest value on each dimension are shown in boldface; the three lowest values on each dimension are shown in italics.

As shown in the MDS graphic representations (Figures 18 – 20), there were clear clustering of sources based on the 2 dimensions. The 14 sources were categorized into three clusters by professional expertise and first-hand knowledge.

Cluster 1 included two sources—“my” experiment and a classmate’s lab report, which had were relatively close to each other in the 2-dimensional graph. This source cluster was low on the level of professional expertise but high on first-hand knowledge.

Cluster 2 included three sources—an anonymous blog, Wikipedia, and science sections of newspaper, which were relatively close to each other in the 2-dimensional graph. This source cluster was low on both dimensions.

Cluster 3 included the other nine sources (e.g., a professor’s post, expert, textbook), which were relatively close to each other in the 2-dimensional graph. This source cluster was high on the level of professional expertise and medium on first-hand knowledge.

These 3 source clusters in the MDS was in part consistent with the 2 factors in the EFA models—trustworthy vs. less trustworthy sources: Cluster 3 sources all loaded on the trustworthy-sources factor, and sources in Clusters 1 and 2 all loaded on the less-trustworthy-sources factors in the EFAs. MDSs, however, clearly revealed the further distinction between sources in the untrustworthy category.

This clustering of sources was consistently found for both purposes (Trust-to-Believe vs. Trust-to-Refute) in all three topic domains (Antifreeze, Corrosion, and Heartburn). These findings suggested that, when rating how trustworthy the 14 sources were, students differentiated 3 types of sources, considering the level of professional expertise and first-hand knowledge of each online source.

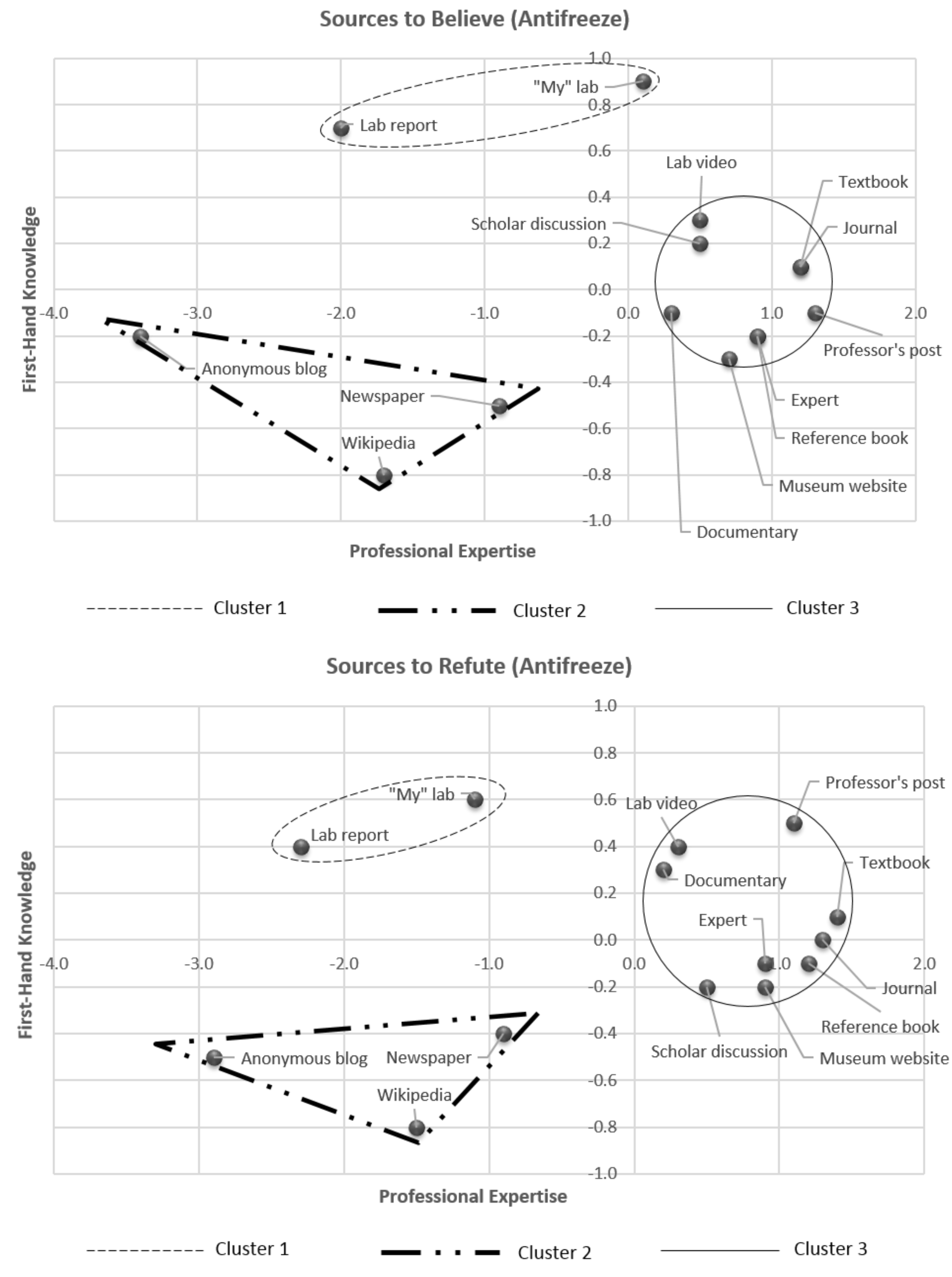


Figure 18. Fourteen sources on 2 dimensions—professional expertise and first-hand knowledge—for developing beliefs (upper) and refuting beliefs (lower) in the topic domain of Antifreeze.

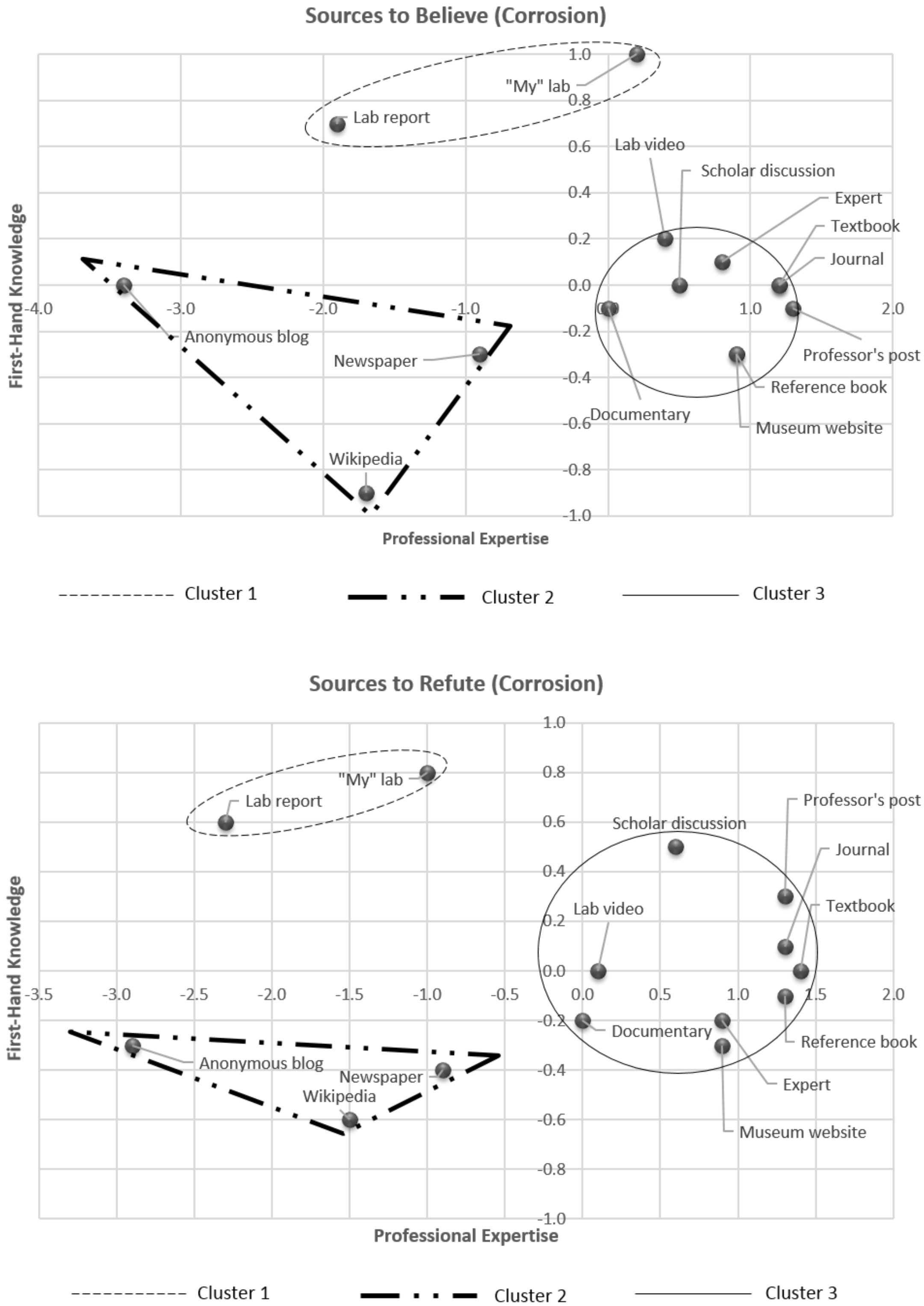
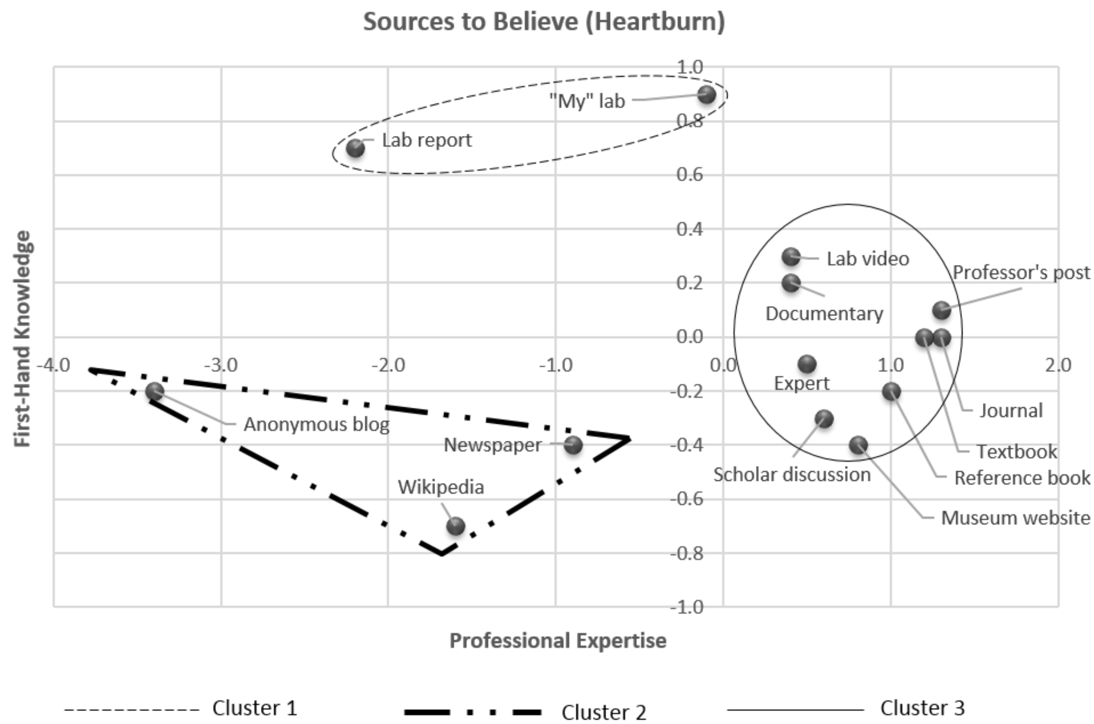


Figure 19. Fourteen sources on 2 dimensions—professional expertise and first-hand knowledge—for developing beliefs (upper) and refuting beliefs (lower) in the topic domain of Corrosion.



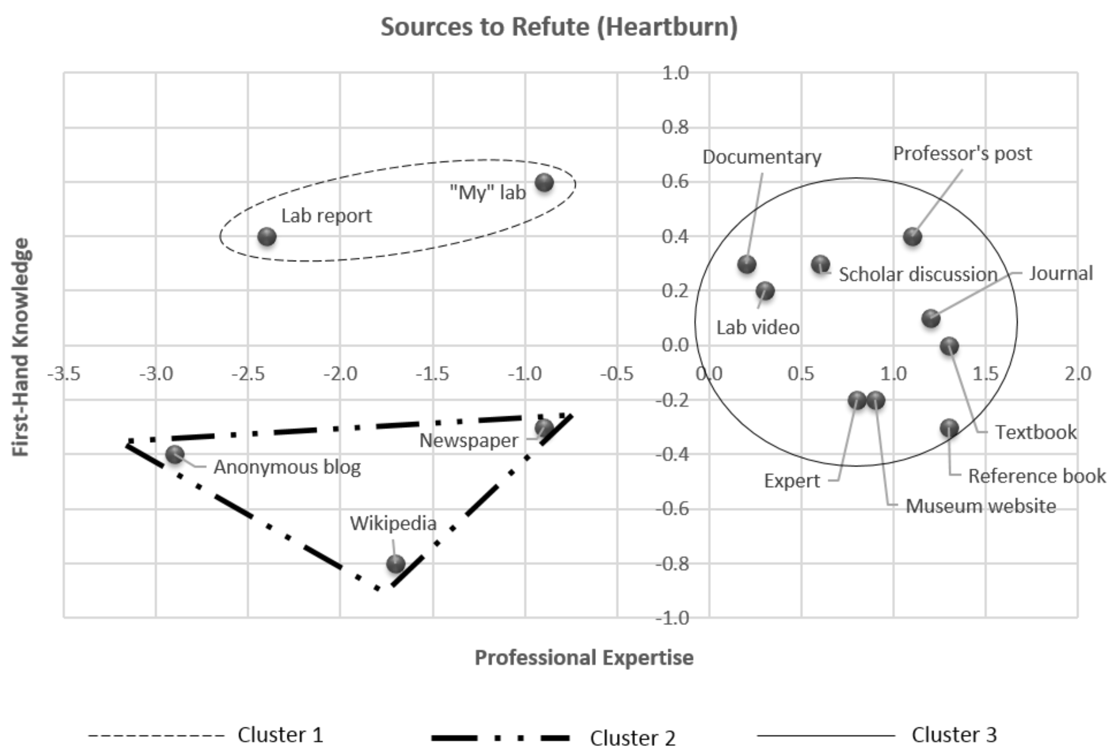


Figure 20. Fourteen sources on 2 dimensions—professional expertise and first-hand knowledge—for developing beliefs (upper) and refuting beliefs (lower) in the topic domain of Heartburn.

In sum, MDS results supported the multidimensionality of sources beliefs. MDS models indicated two perceptual dimensions—level of professional expertise and closeness to first-hand knowledge—on which students rated the 14 sources for their online research. Based on these 2 dimensions, the 14 sources were categorized into 3 clusters, which suggested students trusted the sources to different extents for learning in online research.

Dependent-Measures Tests

In this section, I report dependent-measures MANOVA results about source beliefs—students' rating of sources in trustworthiness—by cluster, by purpose, and by topic. The main purpose was to test whether the three clusters of sources found in the MDSs were in fact different in student-rated trustworthiness, and to compare students' source beliefs in three topic domains (Antifreeze vs. Corrosion vs. Heartburn) and for different purposes (to believe vs. to refute). Specifically, I attempted to answer the following research questions:

RQ2c. Do college students trust multiple sources in online research?

RQ2b. Do college students trust sources differently to believe versus to refute information presented in the webpage posts?

RQ2d. Do college students source beliefs specific to different topics in research?

In brief, MANOVA results indicated that students differentiated the three clusters of sources in terms of how trustworthy they were for learning in online research—Cluster 3 (e.g., professor's post, textbook) rated highest, followed by Cluster 1 ("my" experiment and classmate's lab report), and the lowest-rated Cluster 2 (e.g., Wikipedia, anonymous blog). Students also rated the same sources differently for believing vs. refuting information in the post: Students perceived sources to be more trustworthy if they were using these sources for learning new information about a topic, whereas they perceived the sources to be less trustworthy if these sources contradicted information in the posts. Finally, students did not trust the sources differently for learning different topics.

I computed the average rating of each source cluster based on the MDS results—Cluster 1 (e.g., "my" experiment), Cluster 2 (e.g., Wikipedia), and Cluster 3 (e.g., professor's post) for the two purposes in all three topic domains, and obtained a total of 18 scores (3 clusters × 2 purposes × 3 topics). Given that all scores were nested within individual students, I conducted a dependent-measures MANOVA to detect differences by cluster, by purpose, by topic, and by the interactions (See Table 19 for marginal means and 95% confidence intervals).

Table 19

Estimated Marginal Means by Topic, Purpose, Cluster, and Interaction

Topic	Purpose	Cluster	Source Example	*M*	*S.E.*	95% CI	
						Lower	Upper
Antifreeze				59.9	0.8	58.3	61.5
Corrosion				59.8	0.8	58.4	61.3
Heartburn				59.7	0.8	58.1	61.2
	To believe			65.8	0.8	64.3	67.4
	To refute			53.8	0.9	52.1	55.5
		1		51.6	1.0	49.6	53.6
		2		49.1	1.0	47.2	51.0

Table 19, continued

Topic	Purpose	Cluster	Source Example	*M*	*S.E.*	95% CI	
						Lower	Upper
		3		78.8	0.7	77.4	80.1
Antifreeze							
	To believe			65.5	0.8	63.8	67.1
		1	"My" experiment	60.9	1.2	58.5	63.2
		2	Wikipedia	51.9	1.2	49.6	54.2
		3	Professor's post	83.7	0.7	82.3	85.0
	To refute			54.3	.9	52.5	56.1
		1	"My" experiment	42.3	1.4	39.6	45.0
		2	Wikipedia	46.7	1.2	44.4	49.0
		3	Professor's post	74.0	0.9	72.1	75.8
Corrosion							
	To believe			66.6	.8	65.0	68.3
		1	"My" experiment	62.8	1.2	60.4	65.2
		2	Wikipedia	52.5	1.2	50.2	54.8
		3	Professor's post	84.6	0.7	83.2	85.9
	To refute			53.1	0.9	51.3	54.8
		1	"My" experiment	41.5	1.3	39.0	44.1
		2	Wikipedia	44.5	1.1	42.3	46.8
		3	Professor's post	73.1	1.0	71.3	75.0

Table 19, continued

Topic	Purpose	Cluster	Source Example	*M*	*S.E.*	95% CI	
						Lower	Upper
Heartburn							
	To believe			65.4	0.9	63.703	67.1
		1	"My" experiment	59.3	1.3	56.8	61.8
		2	Wikipedia	53.2	1.1	51.0	55.4
		3	Professor's post	83.6	0.7	82.3	85.0
	To refute			53.9	1.0	52.0	55.8
		1	"My" experiment	42.6	1.3	39.9	45.2
		2	Wikipedia	45.6	1.2	43.3	47.9
		3	Professor's post	73.5	1.0	71.7	75.4

RQ2b. Differences in Source Beliefs by Cluster

MANOVA results showed that the effect of cluster was significant (Wilks' $\Lambda = .190$, $F[2, 352] = 747.995$, $p < .001$, $\eta_p^2 = .810$), suggesting that students rated the three clusters of sources differently. Tests of within-subject contrast implied that, across all topic domains and regardless of purposes, Cluster 3 (e.g., professor's post) was rated the highest ($M = 78.8$, 95% CI [77.4, 80.1]), followed by Cluster 1 (e.g., "my" experiment; $M = 51.6$, 95% CI [50.5, 53.6]), which was rated higher than Cluster 2 (e.g., Wikipedia; $M = 49.1$, 95% CI [47.2, 50.0]).

RQ2c. Differences in Source Beliefs by Purpose

MANOVA results showed that the effect of believing vs. refuting was significant (Wilks' Λ = .525, $F[1, 353] = 319.282$, $p < .001$, $\eta_p^2 = .475$), suggesting a significant difference in students' trust for the 14 sources to believe versus to refute the information in the posts. A test of within-subjects contrast indicated that, across all three topics and regardless of clusters, students rated all sources to be more trustworthy when sources were used to learn a topic ($M = 65.8$, 95% CI [64.3, 67.4]), but they rated the same sources to be less trustworthy when the sources and the presented post had contradictory information about a topic ($M = 53.8$, 95% CI [52.1, 55.5]).

RQ2d. Differences in Source Beliefs by Topic

MANOVA results showed that the effect of topic was nonsignificant (Wilks' Λ = .999, $F[2, 352] = 0.176$, $p = .839$, $\eta_p^2 = .001$), which implied that students' beliefs about these 14 sources were not specific to different topics. The within-subject contrast tests also did not show any pairwise differences among the three topic domains.

Differences in Source Beliefs by Cluster and Purpose

In addition to the main effects of source cluster and purpose (believing vs. refuting), the dependent-measures MANOVA also indicated a significant interaction of cluster and purpose (Wilks' Λ = .623, $F[2, 352] = 106.682$, $p < .001$, $\eta_p^2 = .377$). The cluster × purpose interaction showed that when students used a source to learn new information, they trusted their own experiment or peers' lab report (Cluster 1; $M = 61.0$, 95% CI [58.9, 63.1]) significantly more than they did a source like Wikipedia (Cluster 2; $M = 52.5$, 95% CI [50.4, 54.6]). However, when the webpage post presented information that contradicted a source (e.g., lab results or Wikipedia), they tended to doubt their own lab results and attribute the inconsistency to their mistakes in lab. Therefore, they tended not to trust the lab results enough to refute the information in the post. In other words, students were more likely to use Wikipedia than their own lab results as a support to refute information in the post. In such circumstances, they trusted their lab results (Cluster 1; *M* = 42.1, 95% CI [39.8, 44.5]) less than they did sources such as Wikipedia (Cluster 2; *M* = 45.6, 95% CI [43.6, 47.7]).

For both purposes (Trust-to-Believe and Trust-to-Refute), students perceived Cluster-3 sources (e.g., professor' post) to be the most trustworthy: They trusted these sources strongly to learn information in the post, and when the information was not consistent with Cluster-3 sources, they trusted these sources enough to refute the information presented in the post.

Path Analysis

In this section, I present findings about relations between online learning outcomes and context-specific epistemic aims and source beliefs. The main purpose was to examine whether epistemic aims were related to source beliefs, and whether both epistemic cognition constructs were related to online learning outcomes, controlling for a few demographic variables and perceived ability. Specifically, I conducted bivariate correlations with age, Class (CHEM 1032 vs. CHEM 1031), major (STEM vs. non-STEM), race (White vs. non-White), parent educational attainment, epistemic aims, Cluster-2 source ratings, and online learning outcome. I then specified a path model of learning outcome with related variables to answer the following research question:

RQ3. Are epistemic aims and source beliefs associated with learning outcome in online research on chemistry topics?

In brief, path analysis results indicated that learning outcome was significantly associated with two epistemic aims—justified beliefs and explanatory connection: The more student sought justification, the lower their scores were on the learning outcome measure, but the more students sought explanatory connections between information, the more they tended to obtained higher learning outcome scores. There was also a significant positive association between learning outcome and beliefs about Cluster-2 sources (e.g., Wikipedia, anonymous blog): The more students trusted these sources, the higher their learning outcome scores tended to be. The significant influences of the two epistemic aims and source beliefs were shown to be above and beyond the influences of a number of covariates on learning outcome. Detailed path model results are presented in the following subsections.

Bivariate Correlations

In order to build a path model for relations among learning outcome, epistemic aims, and source beliefs for college students in online research, I first identified the constructs involved in the model. First, the online learning outcome variable was scores on the 15-item learning outcome measure combining the three topic-specific measures (*LO*). Second, the goals variables were the trait-factor scores of epistemic aims and mastery goals, obtained from the MTMM Model a. Third, beliefs about Cluster-2 sources (i.e., Wikipedia, anonymous blogs, and newspaper) for both purposes (to believe and to refute) were most relevant to this context—learning from webpage posts from unknown sources[13]. Fourth, there was a measure of self-perceived ability with sources (*Pcvd*). Lastly, there were a number of student demographic variables, including age (*Age*),

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[13] Students were prompted to read the posts on the 3 chemistry topics from a search online. The sources of these posts were said to be unknown in the instruction of the survey.

gender (*Female*), race (*White*), parent educational attainment (*ParentEd*), year in college (*Year*), major (*STEM*), whether they had learned about the chemistry knowledge involved in the three topics[14] (*Class*), prior experiences in college chemistry courses (*P1031*).

I conducted Pearson correlations of the above-mentioned variables to examine the relations at the bivariate level. As presented in Table 20, online learning outcome was significantly correlated with two epistemic aims (true beliefs and explanatory connection), beliefs about Cluster 2 (Trust-to-Refute), perceived ability with sources, and most of the demographic background variables. The goals variables were correlated with Pcvd, STEM, White, Year, and beliefs about Cluster 2 (Trust-to-Refute). The source beliefs variables were correlated with epistemic aims for explanatory connection, White, and Year. Among all of the demographic variables, P1031 and Female were not significantly correlated with any of the learning outcome, goals, or source beliefs variables, and were hence excluded from the path model.

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[14] As introduced in Chapter 4. Methodology, before the study CHEM 1032 students had learned about the chemistry knowledge involved in the topics in research—buffers in Antifreeze, oxidation in Corrosion, and acids and bases in Heartburn, whereas CHEM 1031 students had not.

Table 20

Bivariate Correlations between Learning Outcome, Goals, Source Beliefs, and Demographic Variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Online Learning Outcome	--															
2. Mastery Goals	.043	--														
3. True Beliefs	.152[b]	.535[b]	--													
4. Justified Beliefs	.006	.716[b]	.575[b]	--												
5. Explanatory Connection	.172[b]	.694[b]	.545[b]	.749[b]	--											
6. SB: Cluster 2 (Believe)	-.016	.054	.059	.024	-.190[a]	--										
7. SB: Cluster 2 (Refute)	-.126[a]	.098	.086	.132[a]	-.012	.708[b]	--									
8. Perceived Ability	.311[b]	.245[b]	.272[b]	.259[b]	.317[b]	.002	-.012	--								
9. Class	.164[b]	-.060	.039	-.011	.042	-.063	-.089	.096	--							
10. Age	.131[a]	-.002	-.022	.038	-.006	.001	-.072	-.095	.010	--						
11. STEM Majors	-.096	.121[a]	.013	.076	.117[a]	-.004	.071	.147[b]	-.014	-.326[b]	--					

Table 20, continued

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
12. Prior CHEM 1031	.074	.026	.003	.035	.031	-.047	-.095	.049	.740[b]	.122[a]	-.021	--				
13. Female	-.053	.065	-.037	-.023	.012	-.088	-.026	-.002	-.086	-.074	.039	-.040	--			
14. White	.280[b]	-.014	.135[a]	.045	.096	-.111[a]	-.140[b]	.071	.113[a]	.033	-.098	.029	-.001	--		
15. Parent Education	.235[b]	-.041	.023	-.018	.033	-.041	-.074	.109[a]	.159[b]	-.084	-.030	.066	-.025	.230[b]	--	
16. Year in College	.102	-.130[a]	-.063	-.067	-.073	-.053	-.113[a]	-.127[a]	.052	.694[b]	-.472[b]	.157[b]	-.090	.082	.010	--
Mean	6.79	0.00	0.00	0.00	0.00	52.51	45.63	83.92	0.64	19.75	0.61	0.77	0.61	0.51	3.74	1.79
SD	2.33	0.94	0.93	1.00	0.93	20.02	19.66	9.52	0.48	2.30	0.49	0.42	0.49	0.50	1.14	1.04

Note. [a] $p < .05$. [b] $p < .01$ (two-tailed). SB = Source Beliefs.

RQ3. Path Model of Learning Outcome, Epistemic Aims, and Source Beliefs

Based on bivariate correlations, epistemic cognition theories (Chinn et al., 2011; Chinn et al., 2014), and the pilot study findings (Dai & Cromley, 2014, April), I built a path model (Figure 21) of 3 sets of endogenous variables, including 4 goals variables, 2 source beliefs variables, and learning outcome. The exogenous variables included Class, Age, STEM, White, ParentEd, Year, and Pcvd. First, learning outcome was hypothesized to be predicted by mastery goals, epistemic aims, source beliefs, and demographic variables (Class, Age, STEM, White, ParentEd, Year, and Pcvd). Second, the source beliefs variables were hypothesized to mediate the effects of mastery goals, epistemic aims, White, ParentEd, and Pcvd. Third, mastery goals and epistemic aims were specified to mediate the effects of STEM, White, Year, and Pcvd.

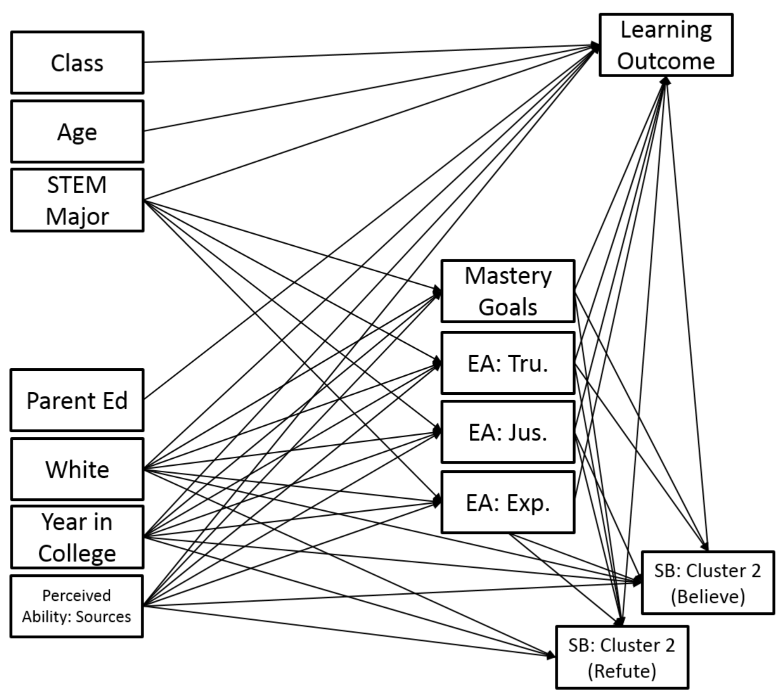

Figure 21. Conceptual path model of learning outcome, mastery goals, epistemic aims, source beliefs, and demographic variables (class, age, major, parent educational attainment, race, year in college), and perceived ability with sources. Error variances and covariances for exogenous variables, and residual variances and covaraínces for endogenous variables are omitted from the figure.

There were 64 parameters estimated in the path model, including the residual variances of all 7 endogenous variables and residual covariances among 4 goals and between the 2 source beliefs. The path model also accounted for error variances and covariances of all 7 exogenous variables. The path model fit the data excellently (x^2 [20] = 16.996, p = .653; RMSEA < .001, 90% CI: < .001, .039; CFI = 1.000; SRMR = .017).

In the rest of the section, I report the model results (Table 21) for the three sets of endogenous variables—1) mastery goals and epistemic aims, 2) source beliefs, and 3) learning outcome.

Table 21

Direct and Indirect Effects on Learning Outcome, Source Beliefs, and Epistemic Aims

Endogenous Variable	Effect	Unstandardized			Standardized		
		Est.	S.E.	*p*	Est.	S.E.	*p*
Learning Outcome	*Direct*						
	Age	0.191	0.066	.004	.195	.065	.003
	White	0.844	0.225	.000	.170	.046	.000
	ParentEd	0.224	0.100	.025	.102	.046	.025
	EA: Jus	-0.670	0.185	.000	-.269	.075	.000
	EA: Exp	0.671	0.196	.001	.252	.073	.001
	Pcvd	0.066	0.012	.000	.280	.049	.000
	SB: Cluster 2 (Believe)	0.015	0.008	.047	.124	.063	.048

Table 21, continued

Endogenous Variable	Effect	Unstandardized			Standardized		
		Est.	S.E.	*p*	Est.	S.E.	*p*
	Indirect						
	STEM-->EA: Jus	-0.089	0.042	.032	-.040	.019	.032
	STEM-->EA: Exp	0.113	0.045	.012	.050	.020	.012
	Pcvd-->EA: Jus	-0.017	0.006	.004	-.071	.025	.005
	Pcvd-->EA: Exp	0.019	0.007	.003	.082	.028	.003
SB: Cluster 2 (Believe)	*Direct*						
	Exp	7.066	1.871	.000	.329	.086	.000
	Indirect						
	Pcvd-->EA: Exp	-0.203	0.064	.001	-.107	.033	.001
	STEM-->EA: Exp	-1.190	0.453	.009	-.066	.025	.008
SB: Cluster 2 (Refute)	*Direct*						
	Jus	-5.143	1.708	.003	-.262	.086	.002
	Exp	-5.702	1.803	.002	-.273	.085	.001
	Indirect						
	Pcvd-->EA: Jus	-0.127	0.050	.012	-.069	.027	.011
	Pcvd-->EA: Exp	-0.164	0.059	.005	-.089	.032	.005
	STEM-->EA: Jus	-0.685	0.344	.046	-.039	.019	.045
	STEM-->EA: Exp	-0.960	0.402	.017	-.054	.023	.016

Table 21, continued

Endogenous Variable	Effect	Unstandardized			Standardized		
		Est.	S.E.	*p*	Est.	S.E.	*p*
Mastery Goals	*Direct*						
	STEM	0.327	0.047	.000	.373	.051	.000
	Pcvd	0.020	0.005	.000	.215	.054	.000
True Beliefs	*Direct*						
	STEM	0.116	0.047	.014	.136	.055	.013
	White	0.237	0.098	.016	.126	.052	.015
	Pcvd	0.024	0.005	.000	.267	.055	.000
Justified Beliefs	*Direct*						
	STEM	0.133	0.050	.008	.148	.055	.007
	Pcvd	0.025	0.005	.000	.263	.055	.000
Explanatory Connection	*Direct*						
	STEM	0.168	0.046	.000	.200	.054	.000
	Pcvd	0.029	0.005	.000	.326	.053	.000

Note. Only significant direct and indirect effects are presented in this table. EA = Epistemic Aims. Mas = Mastery Goals. Tru = True Beliefs. Jus = Justified Beliefs. Exp = Explanatory Connection. Pcvd = Perceived Ability with Sources. ParentEd = Parent Educational Attainment.

Mastery goals and epistemic aims. The path model hypothesized mastery goals and epistemic aims directly associated with 1) major (STEM vs. non-STEM), 2) race (White vs. non-White), 3) year in college, and 4) perceived ability with sources. See model parameter estimates in Figures 22 – 25. The four predictors together explained a medium 13% of variance in mastery goals (Cohen, 1992). On average, these variables explained about 10% of variance in the three epistemic aims (i.e., medium effect sizes according to Cohen, 1992).

The parameter estimates indicated that major and perceived ability with sources to be the common significant predictors of mastery goals (β_{STEM} = 0.373, β_{Pcvd} = 0.215, $p < .001$, respectively) and all three epistemic aims—true beliefs (β_{STEM} = 0.136, $p = .013$; β_{Pcvd} = 0.267, $p < .001$), justified beliefs (β_{STEM} = 0.148, $p = .007$; β_{Pcvd} = .263, $p < .001$), and explanatory connection (β_{STEM} = 0.200, β_{Pcvd} = .326, $p < .001$, respectively). Epistemic aims for true beliefs was also significantly associated with White (β = 0.126, $p = .015$). Of the four hypothesized predictors, Year in college was nonsignificantly associated with any the goal variables. Residual covariances of the 4 goals were significant, indicating positive relations between mastery goals and the three epistemic aims, which was consistent with findings from MTMM Model a.

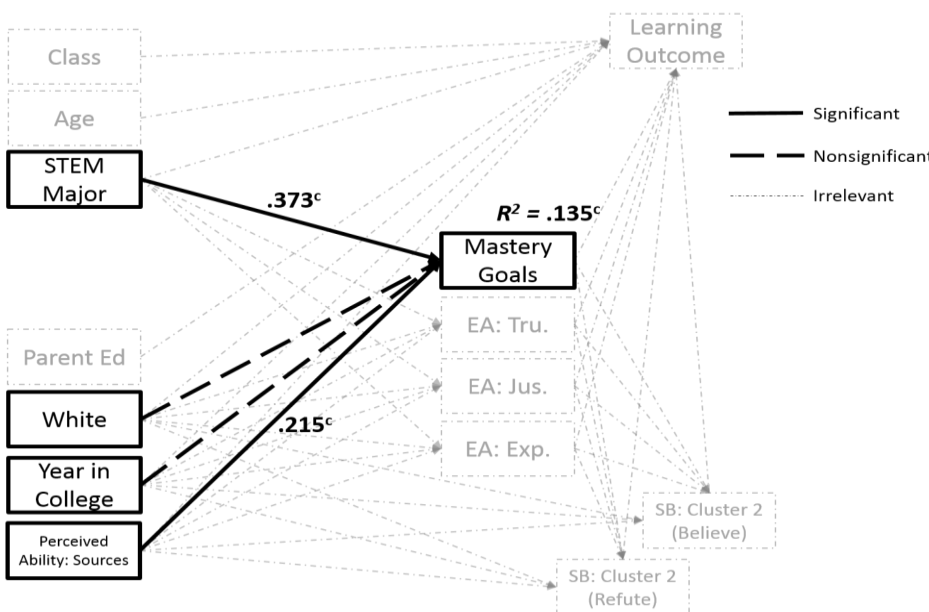

Figure 22. Mastery goals as an endogenous variable in the path model. Highlighted all four predictors of mastery goals, with solid lines indicating significant paths and broken lines indicating nonsignificant paths. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$.

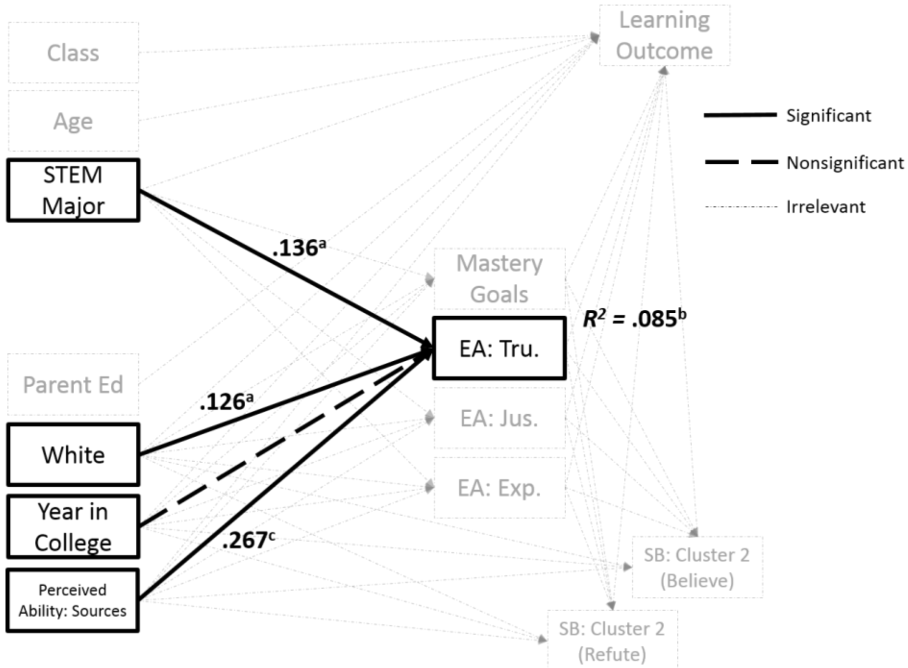

Figure 23. Epistemic aims for true beliefs as an endogenous variable in the path model. Highlighted all four predictors of true beliefs, with solid lines indicating significant paths and broken lines indicating nonsignificant paths. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$.

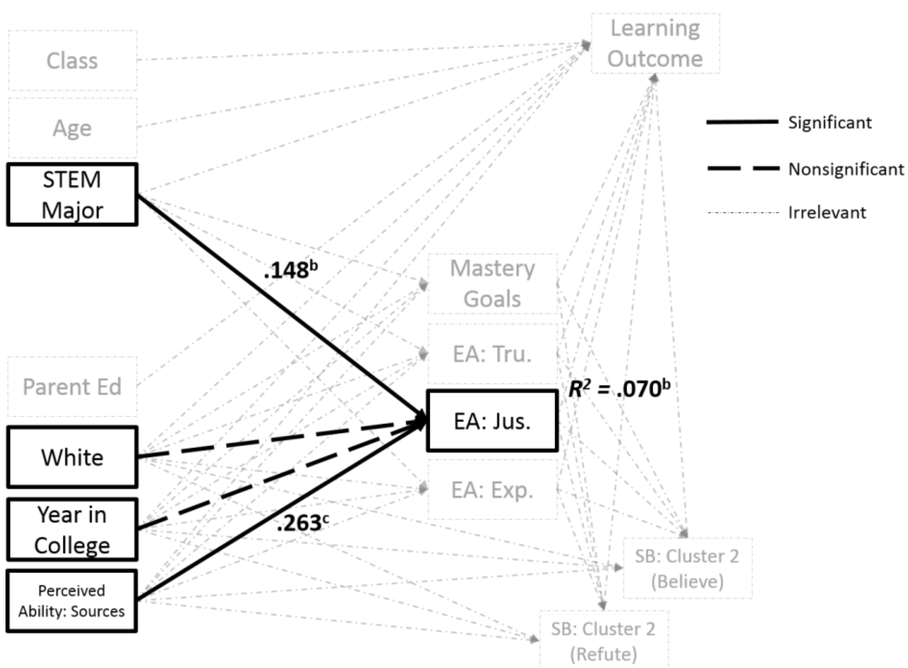

Figure 24. Epistemic aims for justified beliefs as an endogenous variable in the path model. Highlighted all four predictors of justified beliefs, with solid lines indicating significant paths and broken lines indicating nonsignificant paths. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$.

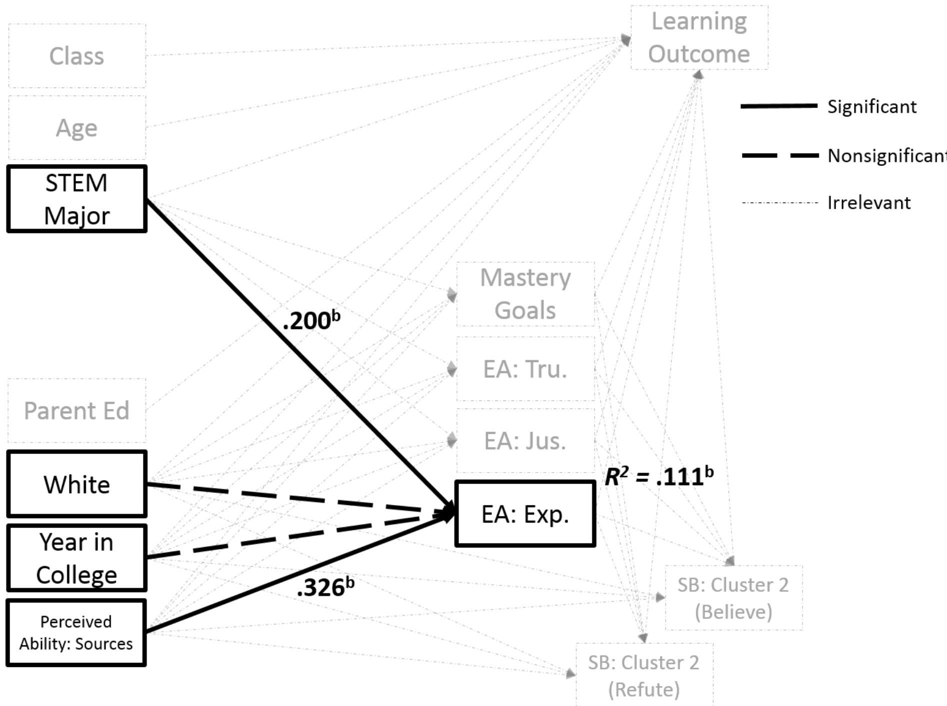

Figure 25. Epistemic aims for explanatory connection as an endogenous variable in the path model. Highlighted all four predictors of explanatory connection, with solid lines indicating significant paths and broken lines indicating nonsignificant paths. ^{a} $p < .05$, ^{b} $p < .01$, ^{c} $p < .001$.

Source beliefs. The model hypothesized that beliefs about Cluster-2 sources (Trust-to-Believe and Trust-to-Believe) would be directly associated with race, year in college, perceived ability, mastery goals, and epistemic aims. In addition, mastery goals and epistemic aims were specified to mediate effects of race, year in college, and perceived ability on both source beliefs. These predictors, however, only accounted for small amounts of variance (6 ~ 8%) in beliefs about Cluster-2 sources.

As shown in Figure 26, the model parameter estimates indicated that beliefs about Cluster-2 sources (Trust-to-Believe) were directly associated with explanatory connection (β = -.329, $p < .001$). There were also two significant indirect effects on this source-beliefs variable—major through explanatory connection (β = -.066, p = .008) and perceived ability through explanatory connection (β = -.107, p = .001).

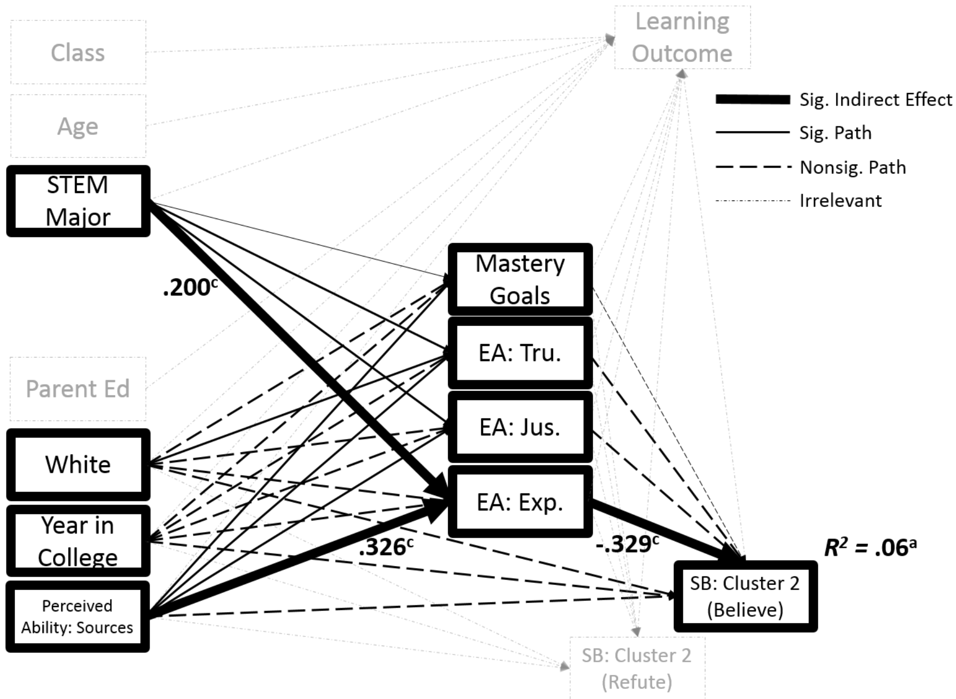

Figure 26. Beliefs about Cluster-2 sources (Trust-to-Believe) as an endogenous variable in the path model. Highlighted all predictors of the variable, with bolded lines indicating significant indirect effects, regular solid lines indicating significant paths, and regular broken lines indicating nonsignificant paths. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$.

As presented in Figure 27, the model parameter estimates showed that beliefs about Cluster-2 sources (Trust-to-Refute) was directly associated with justified beliefs (β = -.262, p = .002) and explanatory connection (β = -.273, p = .001). Additionally, these two epistemic aims were also found to mediate the effects of perceived ability and major on this source-beliefs variable. The four resulting significant indirect effects were perceived ability through justified beliefs (β = -.069, p = .011), perceived ability through explanatory connection (β = -.089, p = .005), major through justified beliefs (β = -.039, p = .045), and major through explanatory connection (β = -.054, p = .016).

The standardized residual covariance between the two source beliefs about Cluster 2 (Trust-to-Believe and Trust-to-Refute) was .695 ($p < .001$), which was consistent with the bivariate correlation between the two variables.

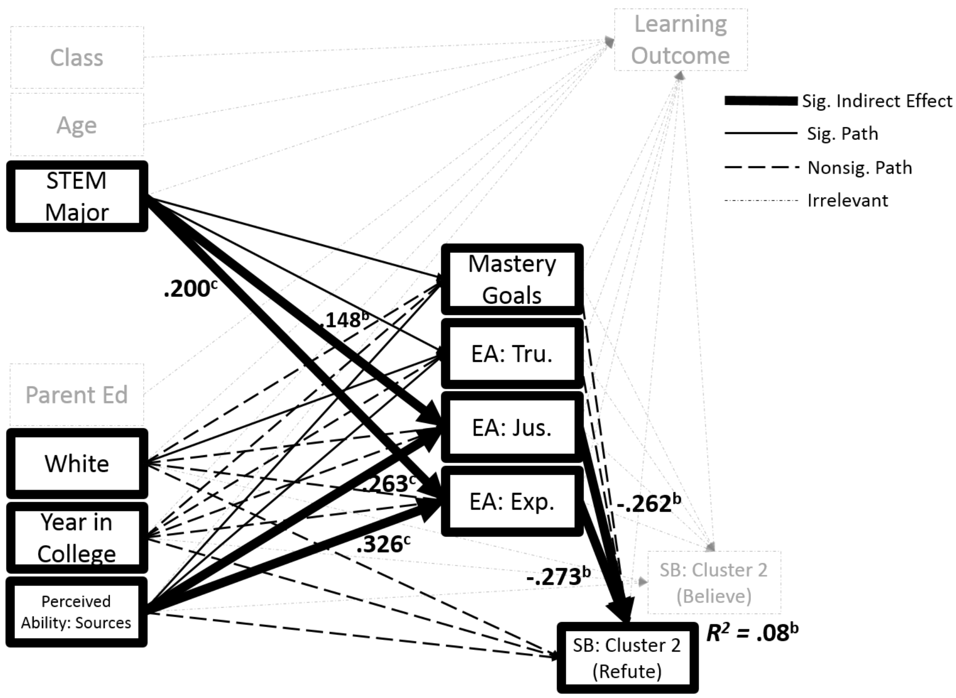

Figure 27. Source beliefs about Cluster-2 sources (Believe-to-Refute) as an endogenous variable in the path model. Highlighted all predictors of the variable, with bolded lines indicating significant indirect effects, regular solid lines indicating significant paths, and regular broken lines indicating nonsignificant paths. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$.

***Learning outcome*.** As shown in Figure 28, the predictors in the path model together accounted for a large 36.6% of variance in scores on the learning outcome measure.

The model parameter estimates showed that learning outcome was directly associated with age ($\beta = .195$, $p = .003$), White ($\beta = .170$, $p < .001$), parent educational attainment ($\beta = .102$, $p = .025$), epistemic aims for justified beliefs ($\beta = -.269$, $p < .001$), epistemic aims for explanatory connection ($\beta = .252$, $p = .001$), perceived ability (β

= .280, *p* < .001), and beliefs about Cluster 2 (Trust-to-Believe; β = .124, *p* = .047). Justified beliefs and explanatory connection mediated the effects of major and perceived ability. The four significant indirect effects were perceived ability through justified beliefs (β = -.071, *p* = .005), perceived ability through explanatory connection (β = .082, *p* = .003), major through justified beliefs (β = -.040, *p* = .032), and major through explanatory connection (β = .050, *p* = .012).

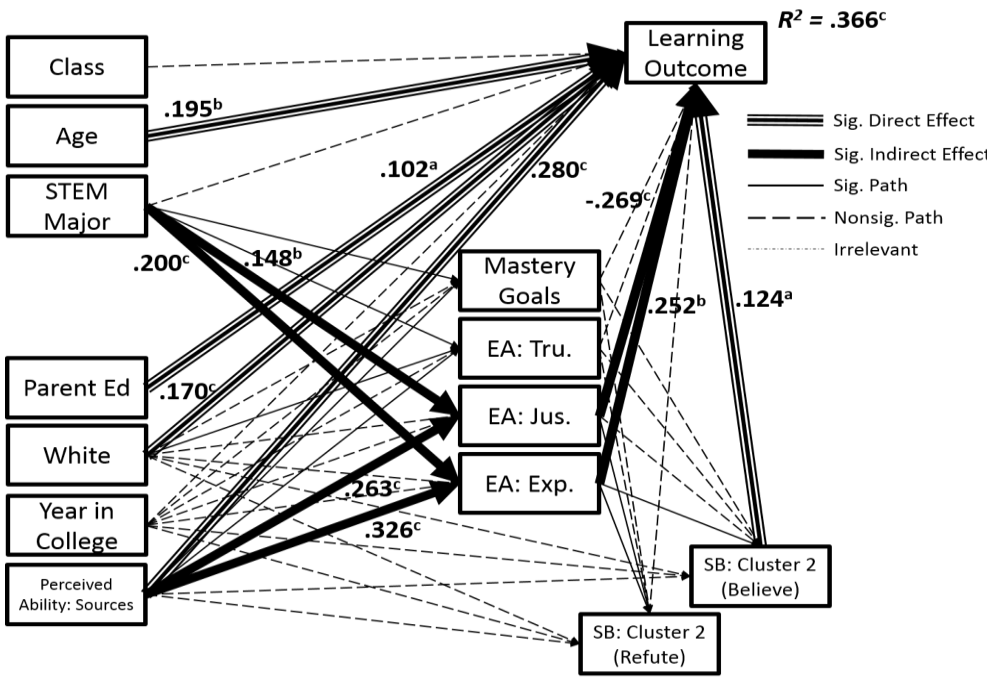

Figure 28. Path model of online learning outcome. Bolded compound lines indicate significant direct effects, bolded solid lines indicate significant indirect effects, regular solid lines indicating significant paths, and regular broken lines indicating nonsignificant paths. [a] $p < .05$, [b] $p < .01$, [c] $p < .001$.

Summary. Epistemic aims for justified beliefs and explanatory connection, as well as beliefs about Cluster 2 (Trust-to-Believe), were found to be predictive of online learning outcome, above and beyond age, parent educational attainment, race, and perceived ability with sources. The two epistemic aims also mediated effects of major and perceived ability with sources on online learning outcome.

CHAPTER 6. DISCUSSION

Epistemic cognition, or personal epistemology (Hofer & Bendixen, 2012), is a complex of cognitions that play an important role in knowing and learning. The present study responded to researchers' call (Chinn et al., 2011; Chinn et al., 2014) for validating epistemic aims, investigating beliefs about sources, and examining the relations between epistemic cognition and learning outcome in a particular context. Claimed to be a central component of epistemic cognition, epistemic aims have not been empirically validated as a construct that has a role in the process of learning. Source beliefs, on the other hand, remain a topic of debate, especially in terms of their dimensionality. In addition, most research on epistemic cognition (e.g., beliefs about sources, beliefs about nature of knowledge) has not focused on measuring epistemic cognition in specific learning contexts, or linking context-specific epistemic cognition to context-specific learning. Therefore, research has not consistently detected the relations between epistemic cognition and learning outcomes.

I aimed to examine two components of epistemic cognition—epistemic aims and source beliefs—in a simulated Internet-based learning context, where college students read online search results (webpage posts) on three chemistry topics—the dangers of antifreeze, corrosion of iron, and heartburn, and completed measures that assessed their learning from reading these texts. I set out to accomplish five goals with this dissertation study: first, to validate three types of epistemic aims and to empirically differentiate the constructs from mastery goals (Ames, 1992b; Elliot & McGregor, 2001); second, to understand students' beliefs about sources; third, to examine whether epistemic aims and source beliefs were specific to learning contexts; fourth, to investigate the relations of epistemic aims, source beliefs, and the learning outcome in an online research context; and, finally, to develop and refine a context-specific self-report measure of epistemic aims and source beliefs.

I sought to answer the following research questions about epistemic aims: (1a) When conducting online research on chemistry topics, do college students set epistemic aims for true beliefs, justified beliefs, and explanatory connection, which can be distinguished from mastery goals? (1b) Are students' epistemic aims specific to the chemistry topics on which they conduct online research? (1c) What is the true-score reliability of the context-specific epistemic aims subscales (true beliefs, justified beliefs, and explanatory connection)?

Results of the study supported the hypothesis that college students set three separable types of epistemic aims—true beliefs, justified beliefs, and explanatory connection—in online research on these chemistry topics. Epistemic aims were found to be distinguished from mastery goals, and were found to be specific to the three chemistry topics used in the research. The measure used to assess context-specific epistemic aims showed excellent subscale reliability and validity.

I also investigated research questions about source beliefs: (2a) Do students evaluate sources based on multiple qualities when conducting online research on chemistry topics? (2b) Do students trust multiple sources in online research? (2c) Do college students trust sources differently to believe versus to refute information presented in the webpage posts? (2d) Do students trust the online sources to different extents for learning different topics?

Findings about source beliefs generally supported the hypothesis that students trust multiple sources for learning from online research on chemistry topics: Students differentiated 3 clusters of the 14 sources based on two qualities of the sources—professional expertise and first-hand knowledge. I found that students trusted sources less (or were more cautious about using the sources) to refute the presented information in the webpage post. However, students did not trust sources differently for the three topics.

Finally, I examined the overall relations among epistemic aims, source beliefs, and the learning outcome: (3) Are epistemic aims and source beliefs associated with learning outcome in the online research on chemistry topics? Results of the path model largely supported the hypothesis that epistemic aims and source beliefs are related to learning outcome in the online research.

In the remainder of this chapter, I will interpret and discuss the results of each research question in further detail. I will then discuss the implications, limitations, and future research directions of the study.

Epistemic Aims

Epistemic aims have been claimed to be a central component of epistemic cognition that determines whether a learner's thinking about material to learn is of an epistemic nature (e.g., for knowing) or of a non-epistemic nature (e.g., for enjoyment; Chinn et al., 2011). However, not only do epistemic aims theoretically resemble mastery goals in the achievement goals theory, they may also manifest as one general goal in the process of learning. Identifying epistemic aims, if they can be separated from mastery goals, may foster understanding about how epistemic cognition contributes to the learning outcome in a specific learning context. In the present study, findings from a series of multitrait-multimethod models and model comparisons provided support for the construct and convergent validity and discriminant validity of epistemic aims, context specificity of the epistemic aims, and the subscale true-score reliability of the context-specific epistemic aims measure.

RQ1a. Epistemic Aims Construct Validation

Epistemic Aims as a Salient Construct

The MTMM model (Model a) that specified 4 trait factors—mastery goals, aims for true beliefs, justified beliefs, and explanatory connection, and 3 method factors—Antifreeze, Corrosion, and Heartburn--fit the data excellently. This provided preliminary evidence for the hypotheses: students set goals—mastering content, true beliefs, justified beliefs, and explanatory connection—in the simulated online research on chemistry topics, and that these goals were indeed distinguished from each other and to some extent correlated.

In the follow-up model comparisons, I compared this excellent-fitting baseline model (Model a) to a number of alternative models, and found that Model a outperformed all of the alternative models in terms of goodness-of-fit. First, Model a fit the data significantly better than Model b which hypothesized that there was no variance in the subscale scores contributed to by goals of any sort. This comparison result indicates *convergent* validity for the *goal* constructs. This finding implies that there were *goals* that manifest in students' responses to the measure while they were on the simulated online research task.

Second, Model a fit the data significantly better than Model c which hypothesized that there was only 1 general goal factor. This comparison result indicates *discriminant* validity for the *goal* constructs. This finding implies that students set *multiple goals* while completing the online research.

Third, Model a fit the data significantly better than Model d which hypothesized that there were only 2 goal factors—a mastery-goal construct and a general epistemic-aim construct (or epistemic aims were a unidimensional construct that was distinguished from mastery goals). This comparison result indicates discriminant validity for *epistemic aims*. This finding implies that in addition to mastery goals students also set at least another type of goals—epistemic aims—while doing the online research.

The excellent model fit and model comparison results in follow-up steps 1-3 showed epistemic aims as a salient construct in students' online research. Chinn and colleagues stated that epistemic aims are "goals related to finding things out, understanding them, and forming beliefs" (Chinn et al., 2011, p. 146). Although it has not been widely examined in research on epistemic cognition (or personal epistemology), the notion of epistemic aims has been discussed in field of philosophy and argued to be important in learning by researchers who study mathematics education (Weber, Inglis, & Mejia-Ramos, 2014) and self-regulated learning (Greene & Yu, 2013, April). Findings of the present study provided empirical supports for the psychological construct of epistemic aims. In the simulated online research, students did set goals to find things out, to understand them, and to form beliefs about them.

An important theoretical and methodological contribution of the present study is the validation of epistemic aims in students' thinking in an online research context, and that epistemic aims were distinguishable from mastery goals in this specific learning context. Chinn and colleagues (2014) claimed that there is no reason to "exclude all aims or goals from the realm of epistemic cognition" (p. 5). In their original work on the expanded epistemic cognitions (Chinn et al., 2011), however, there were limited clarifications about how epistemic aims may be differentiated from mastery goals, or how a measure could operationalize assessing epistemic aims without largely overlapping with examining mastery goals in a specific learning context. They attempted to make such an argument by pointing out some mastery goals are a non-epistemic nature, such as enjoyment (Hulleman et al., 2010), which are clearly not epistemic aims. They also stated that some items on mastery-goals instruments are indeed of an epistemic nature, but it remains unclear whether one could use the items that assess goals of an epistemic nature in the existing mastery-goals instruments, such as PALS (Midgley et al., 2000) and the 2 × 2 achievement-goals measure (Elliot & McGregor, 2001). Overall, it was not clear whether epistemic aims are in fact a salient construct in learning or whether these fine-grained aims about epistemic matters could be measured in a learning context.

In the present study, I developed items that measured aims about epistemic matters, and used a multitrait-multimethod design to empirically distinguish epistemic aims from mastery goals. I deliberately used mastery-goals items that assess goals of an epistemic nature from two widely-used instruments and avoided items of a non-epistemic nature (e.g., enjoyment), to test whether the two constructs were separable in students' thinking. The findings supported the hypothesis that epistemic aims are salient and distinguishable from mastery goals in a learning context of online research: They functioned as separate goals in students' epistemic thinking in the learning process.

Epistemic Aims for True Beliefs

In a more fine-grained examination of epistemic aims, I discovered evidence for differentiating 3 types of epistemic aims from the construct of mastery goals. Model a fit the data significantly better than Model e which hypothesized that mastery goals and epistemic aims for true beliefs were one single construct. This comparison result indicates discriminant validity for *epistemic aims for true beliefs*. This finding implies that students set out to develop true beliefs, which is a different goal from mastery goals.

Chinn et al. (2011) pointed out that one central epistemic aim that people might set is obtaining true (or approaching-the-truth) beliefs (Niiniluoto, 2002), and also avoiding false beliefs. The context-specific measure of epistemic aims in the present study captured both acquiring true beliefs and avoiding false beliefs and the model comparison result provided empirical support for this type of epistemic aims. Theoretically, aims for true beliefs may be a different goal from mastery goals due to the different targets which the goals tackle. Instead of targeting various larger-scale targets (e.g., "to completely master the *material*", "to understand the *content*"; Elliot & McGregor, 2001, p. 504) as mastery goals do, epistemic aims for true beliefs put more focus on fine-scale matters to know, particularly in terms of whether the matter is true, or, in other words, whether a belief accurately represents aspects of the universe (e.g., "to find out what is true", "to know how much … is true"). Therefore, as shown in the present study, mastery goals and aims for true beliefs manifested as two different goals in students' online research.

The finding that students pursued true beliefs in online research is also supported by prior research on epistemic aims: Greene and Yu (2013, April) in their think-aloud study on self-regulated learning in an online context found that students tended to pursue "facts" in their online learning. In another study on goals in online learning, Richter and Schmid (2010) found that students set out to obtain "factual knowledge." In the present study, a crucial criteria these students held was whether or not the information online was true, which suggests that students sought to develop true beliefs about the topic in research.

Epistemic Aims for Justified Beliefs

Similar to Model a vs. Model e, Model a fit the data significantly better than Model f which hypothesized that justified beliefs and mastery goals are one single construct. This comparison result indicates discriminant validity for *epistemic aims for justified beliefs*. The finding implies that students set out to seek justification, which is a different goal from mastery goals.

Chinn and colleagues (2011) pointed out that justified beliefs can also be an epistemic aim people adopt. The notion focuses on *how well* a belief is justified—minimally or sufficiently. The retained items on this epistemic aim[15] in the measure tapped students' thinking on both the quality and quantity of evidence, arguments, and counter-arguments for justification. The model comparison result provided empirical support for this type of epistemic aims. Theoretically, epistemic aims for sufficiently justified beliefs may be different from mastery goals because of the different targets which the goals tackle. Instead of targeting on various larger-scale targets (e.g., "to learn *as much as I can*", "it's important that I *improve my skills*"; Midgley et al., 2000) as

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[15] Note that the 4th item on justified beliefs ("Any evidence would be good enough for me to believe the information about [topic name] in the post.") was omitted from the MTMM analyses due to its unacceptably low item loading on the factor in the EFA models.

mastery goals do, epistemic aims for justified beliefs put more focus on fine-scale matters to know and how well the matter is justified, or, in other words, whether the reasons supporting a belief are adequate (e.g., “to seek evidence for”, “to evaluate whether evidence is strong enough”). Therefore, as shown in the present study, mastery goals and aims for justified beliefs manifested as two different goals in students’ online research.

The finding that students pursued justified beliefs is consistent with prior studies on epistemic aims: In their study of self-regulated learning in an online context, Greene and Yu (2013, April) found that students tended to seek facts that were sufficiently justified. Although in the present study students reported that they wanted to seek justification only at a medium-high level (~ 75), justification was reported as one of the important goals they set out to accomplish in the online research of the three topics.

Epistemic Aims for Explanatory Connection

Model a fit the data significantly better than Model g which hypothesized that explanatory connection and mastery goals are one single construct. This comparison result indicates discriminant validity for *epistemic aims for explanatory connection* (or “understanding” as in Chinn et al., 2011, p. 147). The finding implies that students seek logical connections between items of information, which was a different goal from mastery goals.

Chinn and colleagues (2011) pointed out that people may adopt epistemic aims for grasping explanatory connections between information and seeing how information fits together. The notion focuses on *connections* as opposed to disconnected items of information and the explanatory nature of these connections. The context-specific measure of epistemic aims in the present study examined students’ thinking on the explanation for why certain things happen. The model comparison result provided empirical support for this type of epistemic aims. Theoretically, epistemic aims for explanatory connection may be different from mastery goals due to the different targets which the goals tackle. Instead of targeting the knower developing new understanding about a concept (Elliot & McGregor, 2001) or mastering a new skill (Midgley et al., 2000) as mastery goals do, epistemic aims for explanatory connection put more focus on how well *items* of information suit to each other to form a coherent connection, or, in other words, whether beliefs can be organized in a logical sense (e.g., "to understand why", "to know why things work the way they do") or they are simply a collection of disconnected items. Therefore, as shown in the present study, mastery goals and aims for explanatory connection manifested as two different goals in students' online research.

Chinn and colleagues (2011) specifically pointed out that although there are the conceptual similarities between aims for explanatory connection and mastery goals, it is incorrect to assume equivalence of the two. They argued that there are non-epistemic aspects of learning tapped by some measures of mastery goals, such as enjoyment (Hulleman, Schrager, Bodmann, & Harackiewicz, 2010). The present study did not include any mastery goals items on non-epistemic aspects of learning, and the students' responses still clearly differentiated mastery goals from aims for explanatory connection. The two constructs manifested differently in students' online research on the chemistry topics.

Further Evidence for Three Types of Epistemic Aims

Besides outperforming the above-mentioned alternative models in terms of model fit, Model a also showed solid parameter estimates that were supportive of construct validity. First, all standardized loadings on the trait factors were significant and above .500, suggesting strong influences of mastery goals and epistemic aims on the subscales. Additionally, the true-score inter-factor correlations among mastery goals and epistemic aims ranged from .408 to .639, resulting in approximately 20% to 40% between-factor shared variance, which clearly shows that the 4 goals are related yet distinct constructs that manifest uniquely in students' thinking in their online research.

The positive direction of the relations between mastery goals and epistemic aims showed that seeking mastery of material to learn (i.e., mastery goals) does not contradict adopting any of the three epistemic aims in the context of online research. Compared to the correlations with justified beliefs (r = .638) and with explanatory connection (r = .587), mastery goals seemed to correlate with aims for true beliefs the weakest (r = .476). This may be due to fact that aims for true beliefs can be accomplished merely by strategies such as memorization, whereas adopting mastery goals tends to involve approaches such as seeking explanation and making inferences (Hulleman et al., 2010), which is more in sync with pursuing epistemic aims for justification and explanatory connection.

RQ1b. Context Specificity of Epistemic Aims

In the last step of MTMM model comparison, I discovered evidence for context specificity of epistemic aims. Recall that Model a hypothesized that there were three topics—Antifreeze, Corrosion, and Heartburn—that accounted for the method-related variances in the subscale scores. Model a fit the data significantly better that Model h which hypothesized that there was one general chemistry subject domain that contributed to method-related variances. This comparison result indicates evidence for context specificity of epistemic aims. In scores on each subscale, there was a significant amount of true-score variance explained by the method factors (i.e., topics). These findings all imply that students adopted different goals in their research on different topics.

Research has found that individuals adopt different goals in different learning situations (Chinn et al., 2011; Chinn et al., 2014; Weber et al., 2014). In the present study, the context-specific measure of epistemic aims had three sections each based on a unique topic of research, which may lead to different epistemic aims in the process of online research. Thus, the context specificity of epistemic aims and mastery goals was mainly due to topics, provided that every other aspect of the learning context was controlled to be the same—simulated online research, same physical environment, similar time, and same instruction and supervision.

From the pilot study, I found that the three topics were different in a variety of aspects, such as how familiar they appeared to the students, how interesting they seemed to the students, how much students valued them, and how accessible they seemed to the students. For instance, students in the pilot study reported that they were quite familiar with corrosion of iron and the topic appeared to be less interesting because they could see it in everyday life, which leads to students rating their desire for learn about corrosion at a slightly weaker level. On the other hand, students seemed to find information in the post on heartburn rather foreign and inaccessible because they may have misconceptions about where exactly heartburn happens or to see it or experiment with it in the human body, which leads to students rating their desire for learn about heartburn higher. As Richter and Schmid (2010) explained, students might not care as much about whether information is justified as they would about whether it is true, depending on the topic in research. In the present study, students did report having weaker epistemic aims for justified beliefs about corrosion of iron (M = 74.6; 95% CI: 73.4, 75.8) than they did about heartburn (M = 77.0; 95% CI: 75.8, 78.8), but they had similarly strong aims for true beliefs in both research on corrosion and heartburn.

RQ1c. Measure Psychometrics

In general, the findings show support for adequate psychometric properties (i.e., reliability and validity) of the context-specific epistemic aims questionnaire, which assessed epistemic aims for true beliefs, justified beliefs, and explanatory connection across three topics—Antifreeze, Corrosion, and Heartburn. The 4-trait 3-method model (model a) fit the data excellently and outperformed all other alternative models that I tested, had high trait-factor loadings, and had medium inter-factor correlations. These findings all provide evidence for the construct validity of epistemic aims for true beliefs, justified beliefs, and explanatory connection. The large proportions of true-score (i.e., non-error) variance, in addition to the high internal consistency (measured by Cronbach's alpha), indicate good reliability for the subscales.

Source Beliefs

Beliefs about sources have been extensively studied as an important aspect of epistemic thinking. The dimensionality of source beliefs, however, remains a topic of debate, though the most widely accepted finding has been that individuals' source beliefs form a continuum with one end—believing authority-type sources—to the opposite end—believing personal experience. The former has often been categorized as "naïve" and the latter as "sophisticated" (Hofer, 2001; Olafson & Schraw, 2010).

Chinn et al. (2011) reinstated the importance of seeking multiple sources (including both authority-type sources and personal experimentation) for pursuing knowledge or other epistemic aims, and claimed that it is perfectly legitimate to acquire knowledge or other epistemic achievements from authority-type sources, and that, in some circumstances, it is simply unrealistic to acquire knowledge via personal experimentation or experience. In the present study, findings of a series of multidimensional scaling and dependent-measure MANOVA provided supports for two dimensions of source beliefs (i.e., *professional expertise* and *first-hand knowledge*), based on which students evaluated the trustworthiness of 14 sources for the online research tasks.

RQ2ab. Dimensions of Source Beliefs and Clusters of Sources

The MDS models on 14 sources indicated 2 distinct dimensions—professional expertise and first-hand knowledge—based on which students rated the sources in terms of trustworthiness. This multidimensionality was consistently found in the ratings of the 14 sources for two purposes (Trust-to-Believe and Trust-to-Refute) in three topic domains (Antifreeze, Corrosion, and Heartburn). Consistent with some researchers' viewpoint towards source beliefs (e.g., Chinn et al., 2011), in the present study, it was not the case that students believed *either* authority-type sources *or* personal experience; rather they evaluated a source in terms of both the level of professional expertise and the accessibility or testability.

For example, an experiment demonstration video was considered relatively high on both dimensions, because it is a *public demonstration* of the experiment which implies expertise of conducting the experiment and it shows the *process* which implies accessibility and testability to the students. It was not necessarily rated as high as a scholarly journal article on professional expertise, because it is unknown as to who conducted or posted the video, but students still conceptualized it as “closer” to the other trustworthy sources (Cluster 1, e.g., a professor’s post) than anonymous online sources (Cluster 2, e.g., Wikipedia and a blog whose author is unknown).

The two dimensions of source beliefs found in the present study are consistent with prior studies that examined students’ source evaluation criteria during online research. The dimension, *professional expertise*, is similar to the authority-type sources (Hofer, 2000). In the online context, sources that were considered of high professional expertise may refer to credible authorship (i.e., author’s or publisher’s credentials or the peer-review/editorship process associated with the composition of a particular source), trustworthy source type (e.g., government website), and high evidentiary quality (i.e., evaluations based on supporting data or research findings or citations), as found by List and colleagues in their qualitative study of epistemic criteria for source evaluation (List et al., 2013, April). The dimension, *first-hand knowledge*, is very similar to personal experience as previously found in personal epistemology research (Hofer, 2000). In the online context, sources that were considered of sufficient first-hand knowledge may refer to those that feature high testability and transparency, and consist of comprehensible and straightforward information (List et al., 2013, April).

The MDS results also showed that 14 sources were clustered into 3 types based on the two dimensions, and that each cluster consisted of multiple sources. The findings suggest that students used multiple sources to pursue their epistemic aims in the online research and that they trusted different sources to different extents. Among the three clusters of sources, Cluster 3 (e.g., professor's post, scholarly journal), which was perceived to be high on professional expertise and medium on first-hand knowledge, was rated the highest in trustworthiness. This means that in general students deemed the 9 online sources in Cluster 3 as highly trustworthy to accomplish their epistemic aims in the online research. On the other hand, Cluster 2 (e.g., Wikipedia) was conceived to be the least trustworthy in the three clusters, which may be due to the perceived low professional expertise and the low first-hand knowledge about these online sources.

Students trusted Cluster 1 ("my" experiment and peers' lab report) to a much lower extent compared to Cluster 3, which may be due to the perceived low professional expertise of these sources, even though Cluster 1 sources were considered high on first-hand knowledge. It is plausible that students valued first-hand knowledge less than professional expertise in the context of online research.

RQ2cd. To Believe or not to Believe

In this study, I set out to test whether students trust the sources differently to believe a search result ("I would believe this post if it is from [source name]" versus to refute a search result ("I would no longer believe the post if I read about evidence against it from [source name].") The MANOVA results showed that in general students tended to trust the sources more for developing new beliefs about a topic, and they reported trusting the sources less when there was contradictory information presented to them. The pilot study results provided some insights into this finding: When students were verbalizing their thoughts about sources, they constantly reported that they needed "confirmation" from multiple sources. They stated that even though the source is the professor or an expert, they still needed multiple sources to support their decision to refute a held belief or a learned information (See Examples 11 – 12 in Table 3, Chapter 3). It is possible that students viewed it as a red flag when two sources—any two sources—disagree, and became skeptical and cautious about taking either one for granted.

Note that students were instructed to read an online post on a topic (with URL, author, publisher, etc. blocked from them). The assumption is that they did not know where the post is from or how trustworthy it is. The first set of source-beliefs questions (i.e., Trust-to-Believe) had students directly rate the sources (i.e., "I would believe the information … if the post is from [source name].") Students thus reported to what extent they trusted the 14 sources for them to learn about a topic; that is, to develop new beliefs or learn new information.

The second set of source-beliefs questions (i.e., Trust-to-Refute) added another variable in the picture—the issue of confirmation: The question stem for these questions is, "I would no longer believe the information … if it is inconsistent with [source name]." Essentially, the students were instructed to check the post against each of the 14 sources, which consisted of contradictory information about the topic in research. In this case, students may be cautioned by the disagreement between the post and a source. Even though the source had features of a good source (e.g. high on professional expertise) and it would be considered trustworthy in general, students would probably trust the source less than when there were no contradictions. Therefore, the ratings of all 14 sources were lower in Trust-to-Refute than they were in Trust-to-Believe.

Another interesting finding about agreement between sources is that, although both were rated not too trustworthy (40 ~ 60), Cluster 1 (e.g., "my" experiment) was rated *higher* than Cluster 2 (e.g., Wikipedia) in Trust-to-Believe; however, in Trust-to-

Refute where a source disagrees with information presented in the post, Cluster 1 (e.g., "my" experiment) was rated *lower* than Cluster 2 (e.g., Wikipedia). This finding was consistent with the pilot study results about students' perception of their ability to conduct chemistry experiments: Students generally perceived low competence of experimentation of themselves and their peers (See Examples 13 – 14 in Table 3, Chapter 3). When their experiment results failed to be confirmed by information in the online post, they tended to attribute this to their experimental results being incorrect, and therefore rated their experimental results as an untrustworthy source. However, when students' experiment results were confirmed by information in the post, they tended to trust their experiments more than the non-first-hand, anonymous sources (Cluster 2, such as Wikipedia), because of the first-hand-knowledge feature of experimentation and the additional confirmation from the post.

Relations between Epistemic Aims and Source Beliefs (RQ3)

Epistemic beliefs are associated with learning outcomes and achievement in different subject domains (Cromley et al., in review; Greene et al., 2010; Mason, 2010; Muis, 2004). However, the effects of epistemic beliefs on context-specific learning outcomes has not been consistently found in empirical research (Bråten et al., 2011; Mason et al., 2010a; Mason & Boscolo, 2004; L. Mason & Boldrin, 2008; Strømsø et al., 2011). Some researchers have also pointed out the problem of "low predictive validity of epistemological factors used in ongoing research and various outcome variables" (Schraw & Olafson, 2008, p. 29). One of the main arguments that Chinn and colleagues (2011) made was that including epistemic aims in investigation of epistemic cognition may "improve the explanatory and predictive power" (p. 141) of epistemic cognition for learning processes and outcomes in a learning context. In response to this call, I employed path analysis to model the relations between learning outcome, mastery goals, epistemic aims, and source beliefs in the online research on three topics. A large 36.6% of variance in the learning outcome was accounted for by the model, which provides support for the hypothesis that epistemic aims and source beliefs are associated with learning outcomes in a specific learning context of online research.

Before I proceed to a detailed discussion of the findings, a brief revisit to the learning outcome measure is in need. I designed the learning outcome measure to examine students' comprehension of and application of information in a webpage post, which was supposed to be one of the online search results that the student found when conducting research on a chemistry topic. In order to correctly answer questions in the learning outcome measure, students needed to comprehend the content in the post and the additional information provided in each item, be able to make connections between the post and the questions, and be able to apply concepts and principles in the post to situations given in the questions. Prior knowledge or additional research about the topics were not required; minimal prior knowledge from high-school level chemistry was necessary. Scores on the measure largely reflected the learning outcome in a specific context—a webpage post on a chemistry topic in an online research.

Predicting Learning Outcomes in an Online Learning Context

In the path model, epistemic aims for justified beliefs and explanatory connection, that is, beliefs about Cluster-2 sources (Trust-to-Believe), were found to significantly predict the learning outcome, above and beyond age, parent educational attainment, race, and perceived ability for learning from sources. I will discuss the roles of epistemic aims and source beliefs in the path model of learning outcome in the following subsections.

Epistemic Aims as Predictors of Learning Outcome

Of the four goals, epistemic aims for justified beliefs and epistemic aims for explanatory connection were the only two that had a significant direct effect on the learning outcome ($\beta_{Jus} = -.269$, $p < .001$; $\beta_{Exp} = .252$, $p < .01$). Mastery goals and epistemic aims for true beliefs were not found to be significantly associated with the online learning outcome.

Epistemic aims for explanatory connection. The positive direct effect of explanatory connection on the learning outcome implies that the more students sought coherent connections between pieces of information (or "understanding" as in Chinn et al., 2011) about a topic, the higher they scored on the learning outcome measure. This association was expected, given that the learning outcome measure required in-depth understanding of the post itself and logical inference making, rather than memorizing items of information.

This finding is consistent with prior research on the role of epistemic beliefs in online text comprehension that being able to focus on the text and build a high-quality situation model of the text led to better text comprehension (Bråten et al., 2008). In a recent study on self-regulated learning in online contexts, Greene and Yu (2013, April) also investigated epistemic aims for explanatory connections in the context of self-regulated learning in an online context. Although they did not detect significant relations between this epistemic aim and online learning outcome, they found that explanatory connection aim was associated with better planning and self-regulatory learning strategies. Prior research provided important insights into the positive association between seeking explanatory connection and better online learning outcomes. It is plausible that students who set an epistemic aim for coherent connections within information tended to focus on the presented information in the post and effectively use SRL strategies to build the situation model, which was necessary to correctly solve questions in the context-specific learning outcome measure. In other words, it was adaptive for the learning context that students sought explanatory connections of information in the post.

Epistemic aims for justified beliefs. The negative direct effect of justified beliefs on the learning outcome implied that the more students sought sufficient justification for information presented in the post, the less likely they were able to correctly answer the learning outcome questions. This association was expected, given that the learning outcome measure required in-depth understanding of the post itself and logical inference making, rather than seeking more evidence to support the information in the post.

This finding is also consistent with prior research on the role of epistemic beliefs in online text comprehension: Relying on multiple justifications and personal experimentation was associated with poorer performance in the text comprehension tasks (Bråten et al., 2008). In a study on the role of goals in reading and learning from text, Richter and Schmidt (2010) found that students who sought to constantly validate the justifications for information in a text they were reading tended to be skeptical about the text and focus on information validation with other sources. Although these studies did not directly examine the relations between epistemic aims for justified beliefs and online learning outcome, they provided important insights into the negative association between seeking justified beliefs and the online learning outcome in the present study. It is plausible that students who set an epistemic aim for sufficient justifications tended to be skeptical about information in the post and not focus on the presented information to build the situation model. Their comprehension was negatively affected, which also affected their performance in the learning outcome measure. In other words, it was maladaptive for this specific learning context that students pursued sufficient justification for information in the post.

Source Beliefs as Predictors of Learning Outcome

Regarding the small significant direct effect of source beliefs (Trust-to-Believe; $\beta = .124$, $p < .05$), it suggests that the more students trusted the Cluster-2 sources (e.g., Wikipedia, anonymous blogs, and newspaper science sections), the better they performed on the outcome measure. It is plausible that students perceived the posts to be one of the Cluster-2 sources, because of the appearance of the simulated webpage (e.g., there were no information about author or publisher, the URL was blocked). Given that the task was to learn from this source and answer questions related to the information presented, the more students believed the post (i.e., a Cluster-2 source), the more they might be able to use the information to guide their answers to the learning outcome questions. Weaker beliefs about these sources may mean that students were constantly skeptical about the information presented in the post, and they might want to seek more justification for what they read. Similar to holding an epistemic aims for sufficient justification, doubting the presented information tended to lead to poorer performance in answering the questions in the learning outcome measure.

Trusting Cluster-2 sources may seem to be undesirable or "naïve" as found in some prior research on epistemic beliefs, however, these source beliefs may be more adaptive for this online learning context. As Weber and colleagues pointed out in their work on how expert mathematicians gained conviction, "[m]any purportedly naïve epistemic beliefs and epistemic actions are both natural and correct for some epistemic aims" (Weber et al., 2014, p. 55). Trusting information in the post (i.e., a Cluster-2 source) may be an appropriate source belief to adopt for students' epistemic aims (e.g., explanatory connection) in this online research context, which was a positive influence on the learning outcome. The significant direct effect of explanatory connection on source beliefs ($\beta = .329$, $p < .001$) confirmed this speculation: Those who pursued explanatory connection tended to adopt stronger beliefs about the post (a Cluster-2 source)[16].

Epistemic Aims as Mediators of Effects of Major and Perceived Ability on Learning Outcome

STEM majors. Although there was a nonsignificant direct effect of major (STEM vs. non-STEM) on learning outcome, there were two significant indirect effects of major on learning outcome—one through epistemic aims for justified beliefs ($\beta_{indirect} = -.089$, $p = .032$) and another through epistemic aims for explanatory connection ($\beta_{indirect} = .113$, $p = .012$). This was a full mediation by the two epistemic aims. STEM majors tended to seek both more justifications and more coherent explanatory connections, which was understandable given the topics in research were all related to chemistry courses. The two

[16] Although both direct effect of explanatory connection on source beliefs and the direct effect of source beliefs on learning outcome were significant, the indirect effect of explanatory connection on learning outcome through source beliefs was nonsignificant.

indirect effects of STEM, however, turned out to be a nonsignificant total effect due to the negative influence of aims for justification (i.e., maladaptive in the specific learning context) and the positive influence of aims for explanatory connection (i.e., adaptive in the specific learning context).

This finding facilitates our understanding about the relations between being a STEM major and chemistry learning in an online context. Cromley and associates (in review) found that students' epistemic beliefs (e.g., beliefs about nature of domain knowledge and sources) became less "sophisticated" (Hofer, 2000) during a semester of taking STEM gateway courses. The mediator role of the two epistemic aims may contribute to understanding this phenomenon: It is not necessarily maladaptive to be epistemologically less "sophisticated" in STEM gateway courses, because in most STEM gateway courses, the professor and textbook are the only trustworthy sources for getting the right answers to quizzes, exams, and homework assignments, which may implicitly require students to develop these the less "sophisticated" beliefs and pursue "naïve" epistemic aims in order to adapt to the course context. In other words, these beliefs may seem less "sophisticated" but they may be in fact adaptive for learning in the courses.

The learning context of the present study was to some extent similar to a STEM gateway course: The only source for correction answers to the questions was the webpage post (i.e., a Cluster-2 source). It may not be "sophisticated" to trust the post, but it may be highly appropriate in the learning context and may deliver higher scores on the learning outcome measure. Consistent with prior research (Chinn et al., 2011; Weber et al., 2014), this finding shows that it would be problematic—both conceptually and practically—to consider epistemic cognitions by an absolute scale of “naïve” to “sophisticated” without accounting for the context or understanding epistemic aims.

Perceived ability with sources. In addition to the significant direct effect of perceived ability (β_{direct} = .280, p < .001), there were two significant indirect effects of perceived ability on learning outcome—one through epistemic aims for justified beliefs ($\beta_{indirect}$ = -.017, p =.005) and another through epistemic aims for explanatory connection ($\beta_{indirect}$ = .019, p =.003). This was a partial mediation by the two epistemic aims. Students who perceived higher competence in understanding the online sources tended to seek both more justification and more coherent explanatory connection, which means that higher perceived competence with online sources leads to the pursuit of a deep understanding of the information presented in a source and more justifications from other sources. The two indirect effects of STEM, however, turned out to be a nonsignificant total effect due to the negative influence of aims for justification (i.e., maladaptive in the specific learning context) and the positive influence of aims for explanatory connection (i.e., adaptive in the specific learning context). This finding facilitates our understanding about how epistemic aims setting may be influenced by an individual’s perceived ability: In an online learning context, a learner who perceives better self-competence with online sources tends to be able to comprehend and learn from the information in a source; however, pursuing more justifications and evidence may distract her from learning from this source and, thus, negatively affect learning outcome.

Source Beliefs and Epistemic Aims

In the path model, there were interesting findings about source beliefs: epistemic aims were significantly associated with source beliefs (both Trust-to-Believe and Trust-to-Refute), while none of the demographic variables, perceived ability, or mastery goals had significantly direct effects on source beliefs. Different types of epistemic aims had different influences on source beliefs.

Before proceeding to discussion of the findings, it is necessary to explain a part of the model specification. A possible alternative relation between epistemic aims and source beliefs would be that beliefs about sources determine what epistemic aims an individual may adopt in a learning context. I argue that this would a plausible and perhaps even more reasonable hypothesis to test, had the study been situated in a different context, where researchers examine students' evaluations of different sources (e.g., a health magazine article and a scholarly journal article on the same topic) and have students read both sources and learn about a topic (e.g., stress as a possible cause for hair loss). In this case, students have options in terms of which source(s) to use for learning. Thus, it would be necessary to assess students' beliefs about each source and test whether source beliefs affect the kinds of epistemic aims a student may set for learning about the topic. In the present study, however, students had only one webpage post (per topic) to read and use, and they were instructed to answer questions according to information in the post. How students evaluated the only source was not very important for their epistemic-aims setting; on the contrary, the more students pursued, for instance, coherent connections of information in the post, the more they might consider the post to be trustworthy for correctly answering questions in the learning measure.

Trust-to-Believe. Epistemic aims for explanatory connection had positive associations with trusting Cluster-2 sources (Trust-to-Believe). The finding provides support for the theory that epistemic aims are central to epistemic cognition (Chinn et al., 2011). It would not be meaningful to tap why students would trust sources (e.g. anonymous blogs) without understanding their epistemic aims in this online learning context. Epistemic aims for explanatory connections were found to be negatively associated with trusting Cluster-2 sources. It appeared that students who sought explanatory connections of information in the post tended to be skeptical about Cluster-2 sources. It is plausible that students who wanted deep understandings were not satisfied with sources of this sort, which usually consist of brief information and lack in-depth explanation for the presented information. This epistemic aim also mediated the positive effects of major and perceived ability on source beliefs (Trust-to-Believe). However, a very small amount (R^2 = 6%) of variance in trusting Cluster-2 sources was accounted for by predictors in the path model. This implies that more variables need to be considered in order to better understand beliefs about online sources in a particular learning context.

Trust-to-Refute. Epistemic aims for explanatory connection and justified beliefs were both significantly associated with trusting Cluster-2 sources (Trust-to-Refute). Note that the questions implied contradictions in the post (e.g., "I would no longer believe the information in the post, if it is inconsistent with [source name]"), students needed to trust the sources *enough* to refute presented information in a webpage post.

These beliefs were negatively predicted by aims to seek explanatory connection as well as aims for sufficient justifications. Students who sought deep understanding about the information in a source and those who want to compare and contrast evidences for a claim would not be satisfied with the brief and shallow information contained in a Cluster-2 source (e.g., anonymous blogs). It is plausible that they tended not to trust these sources easily to refute the presented information in the post. However, a very small amount (R^2 = 8%) of variance in trusting Cluster-2 sources (Trust-to-Refute) was accounted for by predictors in the path model. This implies that more variables need to be considered in order to better understand beliefs about online sources in a particular learning context.

Epistemic aims explained a small amount of variance in epistemic beliefs about sources. However, these subtle relations between epistemic aims and source beliefs support the claim that epistemic aims to some extent determine other epistemic cognitions and that without understanding epistemic aims it would not be clear why individuals adopt certain epistemic beliefs in a learning context (Chinn et al., 2011; Weber et al., 2014).

Implications

Theoretical Implications

The present study provided support for the critical role of epistemic aims in epistemic cognition, individuals using multiple sources for learning tasks, the context specificity for epistemic aims, and, most importantly, the associations between epistemic aims, source beliefs, and learning outcome in an online research context. There are important implications for theories of epistemic cognition.

On epistemic aims. Findings from the present study support the salience of epistemic aims in students' thinking in an online research context, and show that epistemic aims were distinguishable from mastery goals by these learners in this specific learning context. Chinn and colleagues (2014) claimed that there is no reason to "exclude all aims or goals from the realm of epistemic cognition" (p. 5). Epistemic aims, as tested in the present study, are fine-grained goals pertaining to truth, justification, and explanation. They can be categorized as one kind of goals, but they should not be deemed as complete equivalencies with mastery goals: Although some mastery goals are also of an epistemic nature (e.g., understanding the material), the targets of the mastery goals are often on the learner developing of a competence and skill, which is different from the target of epistemic aims, which lies in the content to learn.

Epistemic aims for true beliefs, justified beliefs, and explanatory connection are of great theoretical value. Without considering epistemic aims, it would not be meaningful to consider other epistemic cognitions or to assess how these epistemic cognitions may play a role in a learning process. It would be beneficial to expand the scope of epistemic cognition (Chinn et al., 2011) to include epistemic aims: Examining epistemic aims together with other epistemic beliefs (e.g., beliefs about nature of knowledge, justification) may facilitate understanding about why individuals adopt certain epistemic beliefs in specific learning situations.

On the epistemic aim for knowledge. There is an interesting finding related to both true beliefs and justified beliefs in the present study. In philosophical analyses, knowledge is often defined as true, justified beliefs. Findings in this study showed that seeking true beliefs and seeking justified beliefs were conceptualized by the students as two related but different aims, which provided empirical support for Chinn and colleagues' (2011) argument that seeking knowledge involves acquiring true and justified beliefs. The different levels of desire to set goals for true beliefs and for justified beliefs also confirmed that there is a distinction between aiming for true beliefs and aiming for justified beliefs. These findings supported the claims that knowledge, if defined as true justified beliefs, is not the only possible epistemic aim people set in any given circumstances, nor is it the only epistemic achievement people may accomplish in a knowing process (Chinn et al., 2011).

Consistent with prior research (Weber et al., 2014), I found that epistemic aims besides knowledge (i.e., true justified knowledge) may be adopted by individuals (e.g., justified beliefs), and they may be of great value in understanding individuals' knowing and learning in different contexts. Thus, the definition of epistemic cognition or personal epistemology, "beliefs about knowledge and knowing" (Hofer & Pintrich, 1997), may restrict our understanding of how this construct functions in a specific learning context. A possible reason would be that we have assumed that knowledge was the epistemic aim and set out to investigate the acquisition of knowledge and the epistemic cognition involved in the process, when the learner was simply adopting a different epistemic aim (e.g., minimally justified beliefs) in a given context.

On source beliefs. There are multiple dimensions on which individuals evaluate sources of knowledge. The two dimensions—professional expertise and first-hand knowledge—ought to be treated as two distinct dimensions as oppose to two ends of one continuum. The present study explored students' perception of 14 online sources and found the source ratings conceived at least these two dimensions. The dimension, *professional expertise*, bears resemblance to the authority-type sources (or "testimony" as in Chinn et al., 2011), and the dimension, *first-hand knowledge*, has also been found in a number of prior studies (Bråten et al., 2011; Hofer, 2001). Both dimensions constituted as important aspects of a source for students to rate how trustworthy it was for completing the online learning task.

As found in the present study, there were 3 clusters of sources based on the two dimensions of beliefs: Some sources may be high on first-hand knowledge and low on professional expertise and still be considered trustworthy, while some sources may be low on both dimensions and be perceived as untrustworthy. Trusting professional expertise is not necessarily the opposite end of trusting first-hand knowledge on one single continuum. The two dimensions represent very different aspects of a source, and hence should be theorized as two separate dimensions of source beliefs. In response to Chinn and colleagues (2011), findings in the present study supported their claims that believing authority-type sources for knowledge acquisition is perfectly legitimate, and that it should not be labeled as “naïve” beliefs about sources. Similarly, believing first-hand knowledge should now be considered as “sophisticated” without considering the context where learning occurs.

Implications for Research

There are important research and methodological implications of the findings in the present study. First, it is crucial for research on epistemic cognition and learning to assess finer-grained units of epistemic cognition based on the specific context where actual learning tasks take place. Findings of the present study provided strong support for the context specificity of two epistemic cognitions—epistemic aims and source beliefs (Chinn et al., 2011; Hammer & Elby, 2002). That is, epistemic cognitions are context-specific and can be assessed within a particular learning context. Even for the same learning task of online research, individuals set different epistemic aims for different topics; they also trusted the same source differently when the source was confirmed by another source vs. when it was contradicted by another source. In other words, individuals' epistemic cognitions are highly sensitive to the context where learning happens. More attention should be drawn to the context specificity of epistemic cognition, because the domain-general and even domain-specific aspects of epistemic cognition may not be enough for understanding specific epistemic actions and learning outcomes.

Second, emphasizing the role of context in studying epistemic cognition also helps us better gauge epistemic cognitions. It is typical that researchers of epistemic cognition label one end of a dimension (e.g., believing knowledge to be certain and unchanging) as "naïve" epistemic beliefs, and the other end of the continuum (e.g., believing knowledge to be contingent and evolving) as "sophisticated". This way of gauging epistemic beliefs essentially borrows a developmental perspective (i.e., individuals typically go through epistemological development in a direction of naïve to sophisticated) to view the different dimensions of epistemic beliefs (Greene et al., 2008; Hofer & Pintrich, 1997). Although this naïve-sophisticated metric has help us understand epistemic beliefs a lot of larger context, such as domain-general and even domain-specific epistemic beliefs and learning, it can be problematic in studying epistemic cognition in a lot of different contexts. Because this naïve-sophisticated metric gauges epistemic cognition in an absolute term without taking into account the general task, the personal goals, or any other aspects of a learning situation. It often leads to two problems: 1) Due to the mismatch in the scope between epistemic cognition (e.g., domain-general) and learning outcomes (e.g., task-specific), researchers may fail to detect any significant relations between the two (Schraw, 2001; Schraw & Olafson, 2008). 2) Even a relation between epistemic cognition and learning outcome is captured, the result is often confusing (e.g., more “sophisticated” beliefs is associated with poorer task performance; Bråten et al., 2008). It is of utmost importance for research on epistemic cognition to identify the learning context of interest and accordingly measure epistemic cognitions and outcome variables within the defined context. In doing so, epistemic cognitions can be gauged based on the learning goals, outcomes, and other aspects of the context, and researchers can determine what kind of epistemic cognitions are adaptive for a specific learning context.

Third, research on epistemic cognitions and learning ought to investigate multiple epistemic aims in order to capture the complex relations between epistemic cognitions and learning outcomes. The path model clearly depicts the important roles of epistemic aims in the learning process: Different epistemic aims had different influences on beliefs about sources in a learning context. Without considering the epistemic aims, the relations between epistemic cognitions and learning would be ambiguous. In addition to the significant direct effects of epistemic aims on learning outcome, different epistemic aims also mediated effects of other variables (e.g., major) on learning outcome. These findings support that examining epistemic aims increases power of epistemic cognition to explain and predict learning outcomes (Chinn et al., 2011; Chinn et al., 2014). Especially in specific learning situations where the learning task is finer-grained (e.g., comprehending an online text on danger of antifreeze) than skill or competence development (e.g., mastering knowledge about danger of antifreeze), epistemic aims may have more direct influence on learning outcome compared to other types of learning goals (e.g., mastery goals).

Fourth, the context-specific epistemic aims questionnaire (CEAQ) is a quantitative self-report of epistemic cognitions of good psychometric properties. The measure is innovative and of high-quality on a number of aspects. 1) The CEAQ is constructed based on a comprehensive framework of epistemic cognition—Chinn et al. (2011), which is the first one in psychological research to theorize the construct of epistemic aims. 2) The multiple traits and multiple methods considered in the design of the CEAQ warrants examining both the salience of epistemic aims (i.e., trait) and the context specificity of the aims. In addition, the trait-factor scores represent the variance contributed by epistemic aims, which can be used as predictors of other variables of interest. 3) There is strong evidence for measure validity and reliability, including cognitive validity, construct validity, predictive validity, subscale internal consistency, and subscale true-score reliability. 4) The CEAQ measures fine-grained epistemic aims for truth, justification, and explanation, which may capture subtle epistemic thinking and goal setting in a specific learning context.

Implications for Education

The study findings also have important educational implications. First, it may be beneficial to raise students' awareness of the learning context (e.g., specific requirements and challenges of a learning task, available resources in a learning context, and potential restrictions in the context) and encourage students to set epistemic aims, adopt epistemic beliefs, and utilize epistemic strategies that are *adaptive* for the given learning context. As pointed out by Weber and colleagues (2014) and supported by the present study, even some "purportedly undesirable epistemic beliefs and actions" (p. 37; e.g., accepting a result as true without verification, believing an authority-type source) can be appropriate for specific learning situations and yield good learning outcomes. Educators should not promote “sophisticated” epistemic cognitions regardless of context.

Related to the previous point, teachers may help students set adaptive epistemic aims for different learning tasks. Teachers design learning tasks of different sorts to help students learn. It would be immensely helpful for teachers to be explicit about the *adaptive* epistemic aims for students to successfully complete a learning task. For instance, teachers may assign an essay that requires citing three sources to argue for the cause(s) of the Civil War—economic, socio-cultural, or political. If the teacher makes it explicit that regardless of which cause(s) students choose to argue for, the key of the assignment is to find and use three sources that provide justifications for the cause(s) of choice. The instruction clearly directs students to pursue epistemic aims for justifications in the task, which may facilitate searching for consistent arguments and evidence for the cause(s) of their choice, rather than pondering over which one is the “real” cause.

Finally, teachers should explicitly teach source evaluation, especially for online sources. Prior research on Internet-based learning has found that students were not highly competent in online source evaluation, which may lead to misinformation and the formation of misconceptions. Teachers should teach about possible aspects on which students could evaluate a source. Professional expertise and first-hand knowledge, for example, are two aspects a teacher could teach about general source evaluation, but, more importantly, in the case of online sources, teachers should instruct about what are the indicators of professional expertise and first-hand knowledge. In addition to critical evaluation of a source, it is also important for teachers to promote the approach of finding confirmation from multiple sources.

Limitations

The results of this study should be interpreted in light of several limitations. One limitation of the present research was that I was unable to gather a large enough (N ~ 315) sample from CHEM 1032, and had to recruit students from CHEM 1031. Although the total sample size reached the minimum requirement, and there were no significant difference in epistemic cognition between the two cohorts of students, it still led to issues in the analysis. I was unable obtain a uniform prior knowledge measure from the two cohorts: CHEM 1032 students' prior knowledge measure was their prerequisite CHEM 1031 grade, whereas CHEM 1031 students' prior knowledge measure was their Exam 1 scores in the course. Neither turned out to be significantly correlated with online learning outcome measure, and neither was included in the path model for RQ3. The Class variable, however, did function as a prior knowledge variable, because the chemistry knowledge involved in the three topics had been taught to all CHEM 1032 participants in their prior CHEM 1031 class, but not to the CHEM 1031 participants.

Second, the sample contained only students from college chemistry courses. Since the context-specific measure of epistemic aims and source beliefs was not designed to assess domain-specific epistemic cognition, the sample contained mainly students from chemistry courses, which might bias the results with chemistry-course specific variance in the responses to the measure.

Third, the measure did not completely simulate an online research environment. The present design focused on students' learning from one of the many possible search results, rather than presenting multiple sources for students to learn about a topic. There was no choice in terms of which source(s) to use. Therefore, I was unable to investigate students’ actual beliefs about different sources; students’ source beliefs were based on hypothetical scenarios, e.g., “I would believe…if this post is from [source name].”

Another limitation is about the source beliefs subscale. For the purposes of examining students’ evaluation of actual sources rather than confusing them with jargon, I did not write items to directly probe students’ agreement on statements about the hypothesized dimensions (e.g., level of professional expertise); instead, I listed 14 sources and let students rate each of them, and deduced the plausible dimensions using MDS. Although the source ratings indicated clear dimensions and clusters in the MDS, it also introduced a lot of error variance in the rating scores. This probably led the EFAs to fail to extract the two dimensions—professional expertise and first-hand knowledge.

Lastly, findings about the trait consistency of the epistemic-aims measure suggests caution for the use of some subscales. The trait consistency results showed that the *explanatory connection* subscales in all three topic domains had slightly lower trait consistency, especially *explanatory connection in Heartburn*. This finding implies that conclusions about explanatory connection drawn from this subscale might be to some extent weakened by the lower trait consistency, and that one should not draw conclusions solely from the scores on the subscale, *explanatory connection in Heartburn*.

Future Directions

Future research on epistemic aims may explore more epistemic aims that are relevant to different learning outcomes, to enrich our understanding about the role of epistemic aims in learning. Research on source beliefs would benefit from more studies on individuals’ evaluation of multiple sources in a real (i.e., non-simulated) research context. Finally, future research on context-specific epistemic cognition may include epistemic aims, epistemic value, and processes of achieving epistemic aims (Chinn et al., 2014) in the study to understand a full process of accomplishing an epistemic aim, and to examine how other epistemic cognitions function in this process.

Conclusion

This study examined context-specific epistemic aims and source beliefs in the context of online research on three chemistry topics. Construct convergent and discriminant validity of epistemic aims was evident: Students set 3 distinct but correlated epistemic aims—*true beliefs*, *justified beliefs*, *explanatory connection*, which were all distinguished from yet correlated with mastery goals. Students' epistemic aims and mastery goals were specific to the three chemistry topics—*Antifreeze*, *Corrosion*, and *Heartburn*—in this online research.

Students evaluated how trustworthy 14 online sources were based on at least 2 dimensions—*professional expertise* and *first-hand knowledge*. Along these two dimensions, the 14 sources formed 3 clusters of source types, which were perceived as different by the students for their online research. The dimensions and clustering of sources were consistently found in all 6 conditions (Trust-to-Believe vs. Trust-to-Refute in three topic domains).

Students differentiated the three clusters of sources in terms of how trustworthy they were for learning in online research—Cluster 3 (e.g., professor's post, textbook) rated highest, followed by Cluster 1 ("my" experiment and classmate's lab report), and the lowest-rated Cluster 2 (e.g., Wikipedia, anonymous blog). Students also rated the same sources differently for believing vs. refuting information in the post: Students perceived sources to be more trustworthy if they were using these sources for learning new information about a topic, whereas they perceived the sources to be less trustworthy if these sources contradicted information in the posts. Students did not trust the sources differently for learning different topics.

The online learning outcome on the three topics was significantly associated with two epistemic aims—justified beliefs and explanatory connection: The more students sought justifications, the lower their scores were on the learning outcome measure, but the more students sought explanatory connections between information, the more they tended to obtained higher learning outcome scores. There was also a significant positive association between learning outcome and beliefs about Cluster-2 sources (e.g., Wikipedia, anonymous blog): The more students trusted these sources, the higher their learning outcome scores tended to be. The significant influences of the two epistemic aims and source beliefs were shown to be above and beyond the influences of a number of covariates on learning outcome.

The context-specific epistemic aims and source beliefs questionnaire was found to be a high-quality self-report measure with construct validity, predictive validity, internal consistency, and subscale true-score reliability. The measure development and validation contributed to measuring the complex epistemic cognitions.

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APPENDIX A. The Original CEASBQ

You were surfing online and saw a post from the web. It is about a Chemistry topic. Please read the post and respond to a few questions following the instruction:
There are two sets of items (A and B).

A. Please **rate to what extent you agree** with a few statements about learning the topic, on a scale of 0 (*completely disagree*) – 100 (*completely agree*);
B. **Rate how trustworthy** different sources of the information in the post are, on a scale of 0 (*completely disagree*) – 100 (*completely agree*).

Please see the content on a website about antifreeze:

The Danger of Antifreeze
Ethylene glycol, the main component of antifreeze, is metabolized by the liver into glycolic acid. The resulting acidity can exceed the buffering capacity of blood and cause acidosis, a serious condition that results in oxygen deprivation.

A. Please **rate to what extent you agree** with following statements:

1) I would like to know **how much** of the information about antifreeze in the post is **true**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

7) I would like to **have strong evidence for** the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

13) I would like to **know the facts** about antifreeze from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

B. Rate to what extent you agree with the following statements about possible sources of the information in the post, on a scale of 0 (*completely disagree*) – 100 (*completely agree*):

I would believe the information in the post **if**
18) a chemistry professor told me about it. ____
19) I did experiments to test this claim and the results confirmed it. ____
For the one(s) that you rated the highest, please explain why:
____

I would believe the information in the post **ONLY if**
31) a chemistry professor told me about it. ____
32) I did experiments to test this claim and the results confirmed it. ____
For the one(s) that you rated the highest, please explain why:
____

I would DISbelieve (no longer believe) the information in the post **if**
44) a chemistry professor told me that it is wrong. ____

45) I did experiments to test this claim and the results did not confirm it. ____

56) …

For the one(s) that you rated the highest, please explain why: ________________________

You were surfing online and saw a post from the web. It is about a Chemistry topic. Please read the post and respond to a few questions following the instruction:
There are two sets of items (A and B).

A. Please **rate to what extent you agree** with a few statements about learning the topic, on a scale of 0 (*completely disagree*) – 100 (*completely agree*);
B. **Rate how trustworthy** different sources of the information in the post are, on a scale of 0 (*completely disagree*) – 100 (*completely agree*).

Please see the content on a website about corrosion of iron:

Preventing the Corrosion of Iron
The corrosion of iron can be prevented by minimizing the presence of electrolytes and acids, by coating the iron with a sacrificial electrode, or by keeping water out of contact with metal.

A. Please **rate to what extent you agree** with following statements:

1) I would like to know **how much** of the information about corrosion of iron in the post is **true**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

…

(The rest of the subscale omitted in this appendix)

You were surfing online and saw a post from the web. It is about a Chemistry topic. Please read the post and respond to a few questions following the instruction:
There are two sets of items (A and B).

A. Please **rate to what extent you agree** with a few statements about learning the topic, on a scale of 0 (*completely disagree*) – 100 (*completely agree*);
B. **Rate how trustworthy** different sources of the information in the post are, on a scale of 0 (*completely disagree*) – 100 (*completely agree*).

Please see the content on a website about heartburn:

Heartburn
Hydrochloric acid from the stomach sometimes contacts the esophageal lining, resulting in irritation and burning, called heartburn. Heartburn is treated with antacids, bases that neutralize stomach acid.

A. Please **rate to what extent you agree** with following statements:

1) I would like to know **how much** of the information about heartburn in the post is **true**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

…

(The rest of the subscale omitted in this appendix)

APPENDIX B. Demographic Questionnaire

#	Question	Option
1	What is your participant number?	
2	How old are you?	
3	What is your sex?	
		Female
		Male
4	What is your ethnicity?	
		Asian
		Black
		Hispanic/Latino
		Middle Eastern
		White/Caucasian
		Indian subcontinent (India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka, Maldives)
		Native American (Anishinabe, Cherokee, Creek, Iriquois, Mashpee, Navajo, Ojibwe)
		Other
5	What is your mother's (or female guardian's) education?	

#	Question	Option
		Did not graduate from high school
		Graduated from high school
		Some college/Community college
		Bachelor's degree
		Graduate degree (master's, professional, or doctorate)
6	What is your father's (or male guardian's) education?	
		Did not graduate from high school
		Graduated from high school
		Some college/Community college
		Bachelor's degree
		Graduate degree (master's, professional, or doctorate)
7	What is your year in college?	
		Freshman
		Sophomore
		Junior

#	Question	Option
		Senior
		Post-baccalaureate
8	What is your current major?	
9	Have you taken Gen Chem I (1031) before this semester?	
		Yes
		No
10	Have you taken Gen Chem II (1032) before this semester?	
		Yes
		No

Please rate your ability on the following aspects:

On a scale of 0-100, my ability to understand my chemistry professor's posts on our course Blackboard is ______.

On a scale of 0-100, my ability to do chemistry experiments is ______.

On a scale of 0-100, my ability to understand scholarly journal articles in chemistry is ______.

On a scale of 0-100, my ability to understand online discussions by chemistry scholars and experts is ______.

On a scale of 0-100, my ability to understand my classmates' lab reports is ______.

On a scale of 0-100, my ability to understand documentaries on chemistry-related topics is ______.

On a scale of 0-100, my ability to understand video of chemistry experiments is ______.

On a scale of 0-100, my ability to understand chemistry textbooks is ______.

On a scale of 0-100, my ability to understand medical doctors' explanation about a regular disease is ______.

On a scale of 0-100, my ability to understand online blogs is ______.

On a scale of 0-100, my ability to understand the newspaper articles on chemistry topics is ______.

On a scale of 0-100, my ability to understand online encyclopedia like Wikipedia is ______.

On a scale of 0-100, my ability to understand articles on science museum websites is ______.

On a scale of 0-100, my ability to understand the content in chemistry reference books is ______.

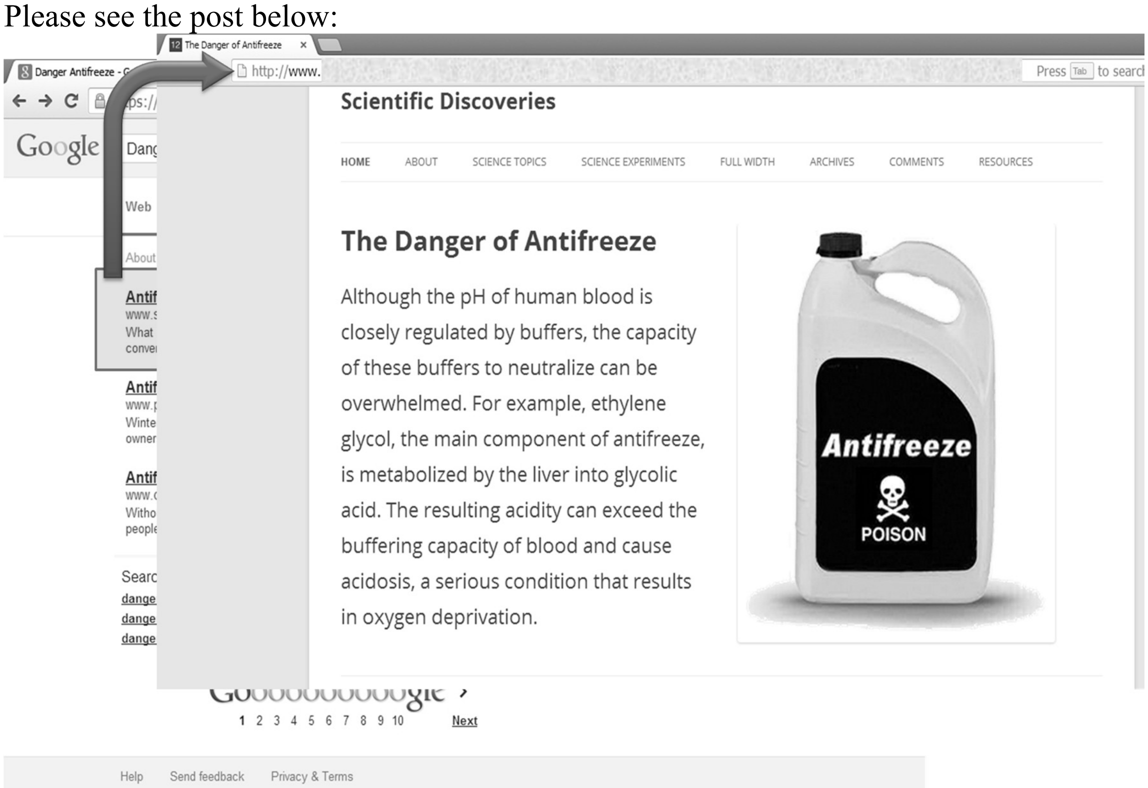
APPENDIX C. The Revised CEASBQ

Suppose you are doing online research on the danger of antifreeze and see a post on this topic from a website. Answer a series of questions about your online learning experience.

Please read the post and respond to three sets of statements (A, B and C) following the instructions:

A. Please **rate how much you agree** with the statements about learning the danger of antifreeze, on a scale of 0 (*completely disagree*) – 100 (*completely agree*);
B. There are many possible sources this post may come from. **Rate how trustworthy each possible source** is to you, on a scale of 0 (*completely disagree*) – 100 (*completely agree*).
C. Make sure you **understand the content of the post** to answer 5 multiple-choice questions.

Please see the post below:



A. Please **rate to what extent you agree** with following statements:

This set of items ask you about the importance of mastering the content in the post:

1) It's **important to me that I learn a lot of new concepts** from this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

2) One of my goals of doing this research is **to learn as much as I can**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

3) One of my goals is **to master a lot of new skills** through this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

4) It's **important to me that I thoroughly understand** the search result.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

5) It's **important to me that I improve my skills** through this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

6) I want to learn as much as possible from this post about antifreeze.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

7) It's very important for me to understand the content of the post about antifreeze.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

8) I desire to completely master the information presented in this post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions ask you about how much you want to find out what is true in the post:

9) I would like to know **how much** of the information about antifreeze in the post is **true**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

10) I would like to know **how much** of the information about antifreeze in the post is **false**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

11) I would like to **get only the true information** about antifreeze from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

12) I would like to **avoid getting false information** about antifreeze from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

13) I would like to find out **what is true** about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

14) I would like to find out **what is false** about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions about you about how much you want to find justification for the post:

15) I would like to **seek evidence for** the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

16) I would like to **know some arguments against** the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

17) I would like to **evaluate whether evidence is strong enough** to support the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

18) **Any evidence would be good enough** for me to believe the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

19) I would like to think about the **arguments for and against** the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

20) I would like to **compare and contrast different evidences** for the information about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions ask you about how much you want to connect pieces of information in the post:

21) I do **not want to understand why** it is dangerous to consume antifreeze.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

22) After reading the post, **all I need to remember is the fact** that antifreeze is dangerous for human body.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

23) I would like to **grasp how the facts are connected** about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

24) I would like to **know the meanings of the terms** in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

25) Regarding the information about antifreeze in the post, I would like to **know why things work the way they do**.

From 0 (*completely disagree*) to 100 (*completely agree*): ________

26) I would like to **know the explanation for the information** about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

B. Listed below are a number of possible sources of the post. Please rate each source in terms of:

a. How trustworthy it is, on a scale of 0 (completely not trustworthy) – 100 (completely trustworthy), and
b. How competent you are in using it, on a scale of 0 (completely unable) – 100 (completely able):

I would believe the information about antifreeze in this post **if**

27) it was posted by my chemistry professor on our course Blackboard site. ____
My ability to understand my chemistry professor's posts on our course Blackboard is ____.
28) it was consistent with the experiment results that I got from lab. ____
My ability to do chemistry experiments is ____.
29) it was from an online scholarly journal article, for example, *Science*. ____
My ability to understand scholarly journal articles is ____.
30) it was one of the posts in an online discussion, in which scholars and experts in chemistry participate. ___
My ability to understand online discussions about topics like this by chemistry scholars and experts.___
31) it was from a classmate's lab report posted on the course Blackboard site. ____
My ability to understand my classmates' lab reports is ____.
32) it is from an online documentary video about patients who consumed antifreeze for various reasons. ____
My ability to understand documentaries like this is ____.
33) it is from a video of an experiment testing this claim and the results confirmed it. ___
My ability to understand video of experiments like this ____.
34) I read about it in the online version of a chemistry textbook. ____
My ability to understand chemistry textbooks ____.
35) it is from a news interview with an ER physician. ____
My ability to understand ER physicians' explanation for matters like this is ____.
36) it is from a WordPress blog whose author is unknown. ____
My ability to understand anonymous blogs is ____.
37) it is from the Health and Science section of a local newspaper, e.g., Philadelphia Inquirer. ____
My ability to understand the Science section of newspapers is ____.

38) it is from an online encyclopedia, e.g. Wikipedia, or www.about.com.
My ability to understand online encyclopedia like Wikipedia ____.
39) it is posted on the website of a science museum, e.g., the Franklin Institute. ____
My ability to understand the posts on science museum websites is ____.
40) it is from the online version of a chemistry reference book. ____
My ability to understand the content in chemistry reference books is____.

For the following set of items, rate ***how much you trust them for you to no longer believe*** *the information in the post, on a scale of 0 – 100:*

I would no longer believe the information about antifreeze in the post **if**

41) I saw evidence against this information stated in my chemistry professor's lecture notes. ____
42) it is inconsistent with the experiment results that I got from lab. ____
43) I read about evidence against this information in a scholarly journal article online, for example, *Science*. ____
44) I read about claims that contradict this information in an online discussion, in which scholars and experts in chemistry participate. ___
45) it is inconsistent with the results in a classmate's lab report. ____
46) it is inconsistent with what I saw from an online documentary video about patients who consumed antifreeze. ____
47) I saw a video of an experiment testing this claim and the results were inconsistent with the information in the post. ___
48) I read about evidence against this information in the online version of a chemistry textbook. ____
49) I saw evidence against this information from a news interview with an ER physician. ____
50) I saw a contradicting claim from a WordPress blog whose author is unknown. ____
51) I read about evidence against this information from the Health and Science section of a local newspaper, e.g., Philadelphia Inquirer. ____
52) I read a contradicting claim from an online encyclopedia, e.g. Wikipedia, www.about.com,
53) I read about evidence against this information on the website of a science museum, e.g., the Franklin Institute. ____
54) I read about evidence against this information in the online version of a chemistry reference book. ____

C. **Based on what you have learned about antifreeze**, answer the five multiple-choice questions:

55) In which part of a human body does the main component of antifreeze—ethylene glycol—get metabolized?
a. Stomach
b. Blood

c. Kidney
d. Liver
e. Lungs

56) Select the INCORRECT statement(s) from the following (Choose as many as apply):
a. A blood gas test, which is used to evaluate oxygenation and acid/base status of blood, can help diagnose whether or not a patient is poisoned by antifreeze.
b. When the acidity rises above the buffering capacity of blood, the pH of blood goes up.
c. Acidosis is a serious condition that results in oxygen saturation.
d. Antifreeze intoxication changes the human body's acid-base balance.

57) Which sample of the following body fluids should be used for ethylene glycol testing?
a. Blood
b. Saliva
c. Vomit
d. Mucus
e. Urine

58) Which of the following is NOT a symptom of antifreeze intoxication?
a. Short of breath or no breathing
b. Organ failure due to acid-base imbalance
c. Blue lips and finger nails
d. Hypertension (high blood pressure)
e. Unconsciousness

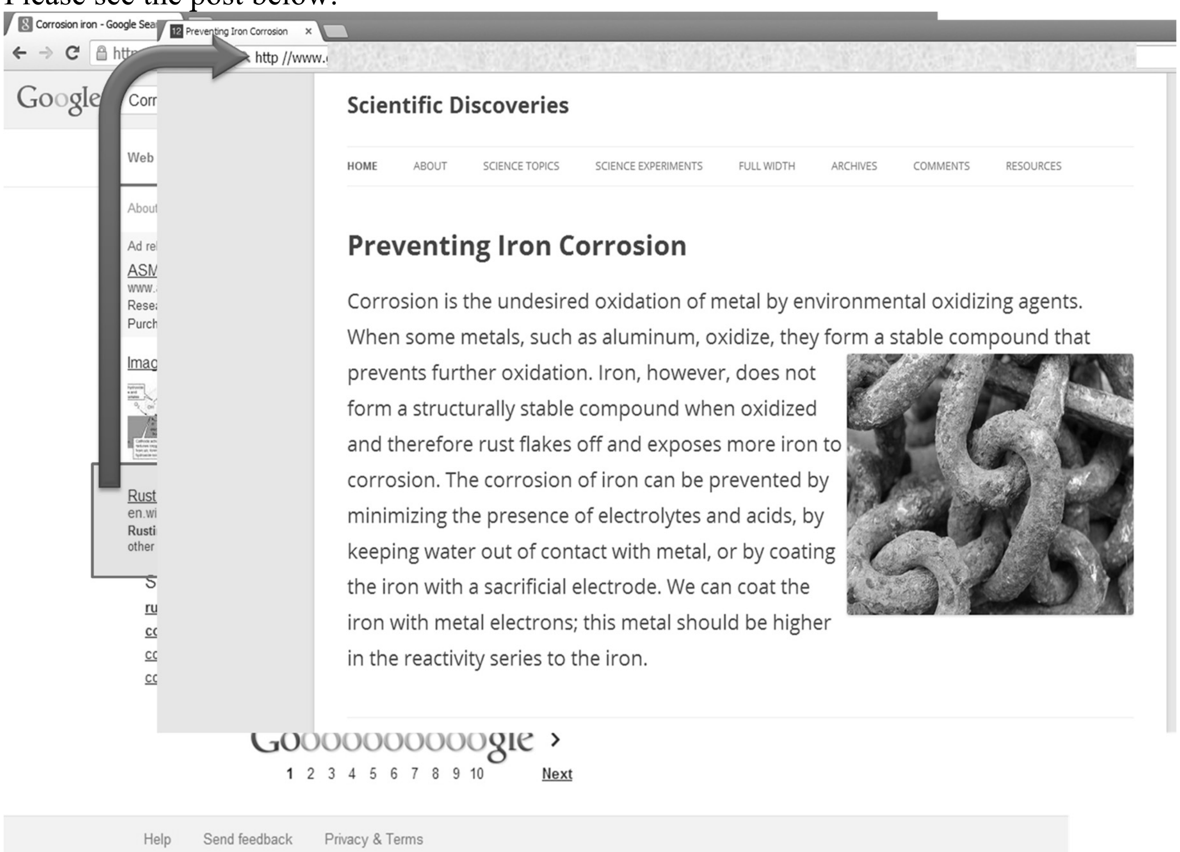
59) Which of the following statement is CORRECT?
a. Ethylene glycol is poisonous because it is metabolized into glycolic acid, which is a strong acid that human body cannot neutralize at all.
b. Antifreeze poisoning causes respiratory acidosis.
c. The excessive glycolic acid caused by antifreeze poisoning can be treated with antacids, bases that neutralize stomach acidity.
d. Antifreeze poisoning is a medical emergency, and intensive care is needed immediately.

Suppose you are doing online research on corrosion of iron and see a post on this topic from a website. Answer a series of questions about your online learning experience.

Please read the post and respond to three sets of statements (A, B and C) following the instructions:

A. Please **rate how much you agree** with the statements about learning the corrosion of iron, on a scale of 0 (*completely disagree*) – 100 (*completely agree*);
B. There are many possible sources this post may come from. **Rate how trustworthy each possible source** is to you, on a scale of 0 (*completely disagree*) – 100 (*completely agree*).
C. Make sure you **understand the content of the post** to answer 5 multiple-choice questions.

Please see the post below:



A. Please **rate to what extent you agree** with following statements:

This set of items ask you about the importance of mastering the content in the post:

1) It's **important to me that I learn a lot of new concepts** from this research. From 0 (*completely disagree*) to 100 (*completely agree*): ________

2) One of my goals of doing this research is **to learn as much as I can**.

3) One of my goals is **to master a lot of new skills** through this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

4) It's **important to me that I thoroughly understand** the search result.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

5) It's **important to me that I improve my skills** through this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

6) I want to learn as much as possible from this post about corrosion.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

7) It's very important for me to understand the content of the post about corrosion.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

8) I desire to completely master the information presented in this post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions ask you about how much you want to find out what is true in the post:

9) I would like to know **how much** of the information about corrosion in the post is **true**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

10) I would like to know **how much** of the information about corrosion in the post is **false**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

11) I would like to **get only the true information** about corrosion from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

12) I would like to **avoid getting false information** about corrosion from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

13) I would like to find out **what is true** about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

14) I would like to find out **what is false** about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions about you about how much you want to find justification for the post:

15) I would like to **seek evidence for** the information about corrosion in the post.

From 0 (*completely disagree*) to 100 (*completely agree*): ________

16) I would like to **know some arguments against** the information about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

17) I would like to **evaluate whether evidence is strong enough** to support the information about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

18) **Any evidence would be good enough** for me to believe the information about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

19) I would like to think about the **arguments for and against** the information about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

20) I would like to **compare and contrast different evidences** for the information about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions ask you about how much you want to connect pieces of information in the post:

21) I do **not want to understand why** it is dangerous to consume corrosion.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

22) After reading the post, **all I need to remember is the fact** that corrosion is dangerous for human body.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

23) I would like to **grasp how the facts are connected** about corrosion in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

24) I would like to **know the meanings of the terms** in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

25) Regarding the information about corrosion in the post, I would like to **know why things work the way they do**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

26) I would like to **know the explanation for the information** about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

B. Listed below are a number of possible sources of the post. Please rate each source in terms of:

a. How trustworthy it is, on a scale of 0 (completely not trustworthy) – 100 (completely trustworthy), and
b. How competent you are in using it, on a scale of 0 (completely unable) – 100 (completely able):

I would believe the information about antifreeze in this post **if**

27) it was posted by my chemistry professor on our course Blackboard site. ____
My ability to understand my chemistry professor's posts on our course Blackboard is ____.

28) it was consistent with the experiment results that I got from lab. ____
My ability to do chemistry experiments is ____.

29) it was from an online scholarly journal article, for example, *Science*. ____
My ability to understand scholarly journal articles is ____.

30) it was one of the posts in an online discussion, in which scholars and experts in chemistry participate. ___
My ability to understand online discussions about topics like this by chemistry scholars and experts.___

31) it was from a classmate's lab report posted on the course Blackboard site. ____
My ability to understand my classmates' lab reports is ____.

32) it is from an online documentary video about rusting of boats and ships. ____
My ability to understand documentaries like this is ____.

33) it is from a video of an experiment testing this claim and the results confirmed it. ___
My ability to understand video of experiments like this ____.

34) I read about it in the online version of a chemistry textbook. ____
My ability to understand chemistry textbooks ____.

35) it is from a news interview with an engineer who has expertise in preventing corrosion of machinery. ____
My ability to understand engineers' explanation for matters like this is ____.

36) it is from a WordPress blog whose author is unknown. ____
My ability to understand anonymous blogs is ____.

37) it is from the Health and Science section of a local newspaper, e.g., Philadelphia Inquirer. ____
My ability to understand the Science section of newspapers is ____.

38) it is from an online encyclopedia, e.g. Wikipedia, or www.about.com.
My ability to understand online encyclopedia like Wikipedia ____.

39) it is posted on the website of a science museum, e.g., the Franklin Institute. ____
My ability to understand the posts on science museum websites is ____.

40) it is from the online version of a chemistry reference book. ____
My ability to understand the content in chemistry reference books is____.

For the following set of items, rate ***how much you trust them (0 – 100) for you to no longer believe*** *the information in the post:*

41) I saw evidence against this information stated in my chemistry professor’s lecture notes. ____
42) it is inconsistent with the experiment results that I got from lab. ____
43) I read about evidence against this information in a scholarly journal article online, for example, *Science*. ____
44) I read about claims that contradict this information in an online discussion, in which scholars and experts in chemistry participate. ___
45) it is inconsistent with the results in a classmate’s lab report. ____
46) it is inconsistent with what I saw from an online documentary video rusting of boats and ships. ____
47) I saw a video of an experiment testing this claim and the results were inconsistent with the information in the post. ___
48) I read about evidence against this information in the online version of a chemistry textbook. ____
49) I saw evidence against this information from a news interview with an engineer who has expertise in preventing corrosion of machinery. ____
50) I saw a contradicting claim from a WordPress blog whose author is unknown. ____
51) I read about evidence against this information from the Science section of a local newspaper, e.g., Philadelphia Inquirer. ____
52) I read a contradicting claim from an online encyclopedia, e.g. Wikipedia, www.about.com,
53) I read about evidence against this information on the website of a science museum, e.g., the Franklin Institute. ____
54) I read about evidence against this information in the online version of a chemistry reference book. ____

C. **Based on what you have learned about corrosion**. Answer a few questions below:

55) Based on the information on corrosion, which of the element is not part of the compound of rust?
    a. Fe
    b. N
    c. Cl
    d. O

56) Select the INCORRECT statement(s) from the following (Choose as many as apply):
    a. Iron that is exposed to air may rust in time.
    b. Unlike iron, aluminum cannot be oxidized.
    c. Any metal can be applied to iron to serve as the sacrificial electrode.
    d. Any method which will exclude air from the iron will prevent corrosion.

57) Greasing iron nails with oil can prevent the nails from corrosion. What purpose does the oil NOT serve?
    a. Keeping water out of contact with iron

b. Serving as a sacrificial electrode
c. Minimizing the presence of electrolytes
d. Preventing water-based acids from contacting the iron

58) Which of the following is NOT a correct way to prevent iron corrosion? (Choose as many as apply)

a. Painting water-proof paint on the iron
b. Galvanizing (coating the iron with zinc) the iron
c. Coating silver on the iron to serve as the sacrificial electrode
d. Greasing the iron with machine oil
e. Placing the iron in a 10% salt solution

59) Which of the following statement is CORRECT? (Choose as many as apply)

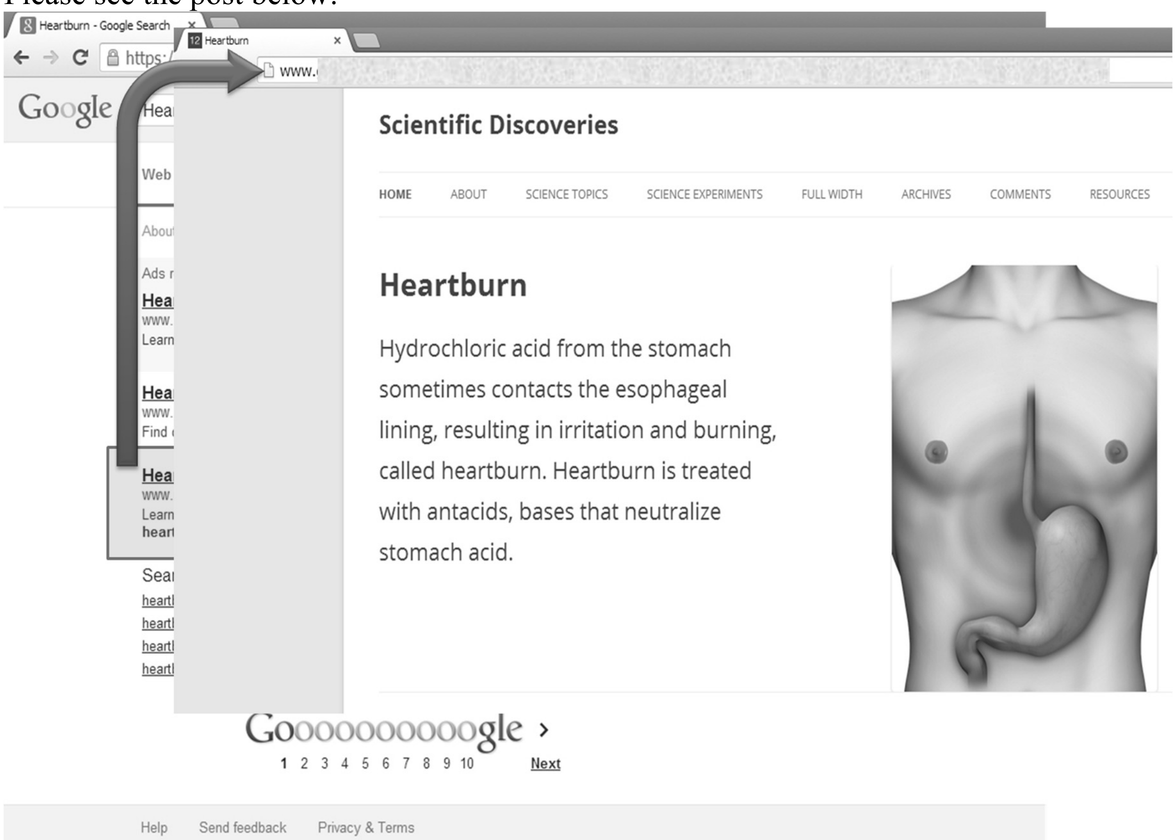
a. Iron forms a structurally stable compound when oxidized.
b. Metals whose reactivity is lower than iron are ideal to use as the sacrificial electrode to prevent iron corrosion.
c. Corrosion stabilizes the structure of metals.
d. Although greasing iron can prevent corrosion, it would not be realistic to grease water pipes with oil to prevent them from rusting.
e. Corrosion is an oxidation of metals.

Suppose you are doing online research on the heartburn and see a post on this topic from a website. Answer a series of questions about your online learning experience.

Please read the post and respond to three sets of statements (A, B and C) following the instructions:

A. Please **rate how much you agree** with the statements about learning the heartburn, on a scale of 0 (*completely disagree*) – 100 (*completely agree*);
B. There are many possible sources this post may come from. **Rate how trustworthy each possible source** is to you, on a scale of 0 (*completely disagree*) – 100 (*completely agree*).
C. Make sure you **understand the content of the post** to answer 5 multiple-choice questions.

Please see the post below:



A. Please **rate to what extent you agree** with following statements:

This set of items ask you about the importance of mastering the content in the post:

1) It's **important to me that I learn a lot of new concepts** from this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

2) One of my goals of doing this research is **to learn as much as I can**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

3) One of my goals is **to master a lot of new skills** through this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

4) It's **important to me that I thoroughly understand** the search result.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

5) It's **important to me that I improve my skills** through this research.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

6) I want to learn as much as possible from this post about heartburn.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

7) It's very important for me to understand the content of the post about heartburn.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

8) I desire to completely master the information presented in this post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions ask you about how much you want to find out what is true in the post:

9) I would like to know **how much** of the information about heartburn in the post is **true**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

10) I would like to know **how much** of the information about heartburn in the post is **false**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

11) I would like to **get only the true information** about heartburn from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

12) I would like to **avoid getting false information** about heartburn from the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

13) I would like to find out **what is true** about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

14) I would like to find out **what is false** about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions about you about how much you want to find justification for the post:

15) I would like to **seek evidence for** the information about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

16) I would like to **know some arguments against** the information about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

17) I would like to **evaluate whether evidence is strong enough** to support the information about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

18) **Any evidence would be good enough** for me to believe the information about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

19) I would like to think about the **arguments for and against** the information about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

20) I would like to **compare and contrast different evidences** for the information about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

This set of questions ask you about how much you want to connect pieces of information in the post:

21) I do **not want to understand why** it is dangerous to consume heartburn.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

22) After reading the post, **all I need to remember is the fact** that heartburn is dangerous for human body.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

23) I would like to **grasp how the facts are connected** about heartburn in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

24) I would like to **know the meanings of the terms** in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

25) Regarding the information about heartburn in the post, I would like to **know why things work the way they do**.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

26) I would like to **know the explanation for the information** about antifreeze in the post.
From 0 (*completely disagree*) to 100 (*completely agree*): ________

B. Listed below are a number of possible sources of the post. Please rate each source in terms of:

a. How trustworthy it is, on a scale of 0 (completely not trustworthy) – 100 (completely trustworthy), and
b. How competent you are in using it, on a scale of 0 (completely unable) – 100 (completely able):

I would believe the information about antifreeze in this post **if**

27) it was posted by my chemistry professor on our course Blackboard site. ____
My ability to understand my chemistry professor's posts on our course Blackboard is ____.

28) it was consistent with the experiment results that I got from lab. ____
My ability to do chemistry experiments is ____.

29) it was from an online scholarly journal article, for example, *Science*. ____
My ability to understand scholarly journal articles is ____.

30) it was one of the posts in an online discussion, in which scholars and experts in chemistry participate. ___
My ability to understand online discussions about topics like this by chemistry scholars and experts.___

31) it was from a classmate's lab report posted on the course Blackboard site. ____
My ability to understand my classmates' lab reports is ____.

32) it is from an online documentary video about patients who suffer from chronic heartburn for various reasons. ____
My ability to understand documentaries like this is ____.

33) it is from a video of an experiment testing this claim and the results confirmed it. ___
My ability to understand video of experiments like this ____.

34) I read about it in the online version of a chemistry textbook. ____
My ability to understand chemistry textbooks ____.

35) it is from a news interview with a medical doctor. ____
My ability to understand medical doctors' explanation for matters like this is ____.

36) it is from a WordPress blog whose author is unknown. ____
My ability to understand anonymous blogs is ____.

37) it is from the Health and Science section of a local newspaper, e.g., Philadelphia Inquirer. ____

My ability to understand the Health and Science section of newspapers is ____.

38) it is from an online encyclopedia, e.g. Wikipedia, or www.about.com. My ability to understand online encyclopedia like Wikipedia ____.

39) it is posted on the website of a science museum, e.g., the Franklin Institute. ____ My ability to understand the posts on science museum websites is ____.

40) it is from the online version of a chemistry reference book. ____ My ability to understand the content in chemistry reference books is____.

For the following set of items, rate ***how much you trust them for you to no longer believe*** *the information in the post, on a scale of 0 – 100:*

41) I saw evidence against this information stated in my chemistry professor's lecture notes. ____

42) it is inconsistent with the experiment results that I got from lab. ____

43) I read about evidence against this information in a scholarly journal article online, for example, *Science*. ____

44) I read about claims that contradict this information in an online discussion, in which scholars and experts in chemistry participate. ___

45) it is inconsistent with the results in a classmate's lab report. ____

46) it is inconsistent with what I saw from an online documentary video about patients who suffer from chronic heartburn. ____

47) I saw a video of an experiment testing this claim and the results were inconsistent with the information in the post. ___

48) I read about evidence against this information in the online version of a chemistry textbook. ____

49) I saw evidence against this information from a news interview with a family doctor. _

50) I saw a contradicting claim from a WordPress blog whose author is unknown. ____

51) I read about evidence against this information from the Health and Science section of a local newspaper, e.g., Philadelphia Inquirer. ____

52) I read a contradicting claim from an online encyclopedia, e.g. Wikipedia, www.about.com,

53) I read about evidence against this information on the website of a science museum, e.g., the Franklin Institute. ____

54) I read about evidence against this information in the online version of a chemistry reference book. ____

C. **Based on what you have learned about heartburn**. Answer a few questions below:

55) In which part of a human body does heartburn usually occur?
   a. Stomach
   b. Esophagus
   c. Chest bones
   d. Heart

56) Which of the following statement is INCORRECT based on the information on heartburn?

a. The logic behind treating heartburn with antacids is to neutralize the hydrochloric acid with bases.
b. Although the name may imply the heart, heartburn has nothing to do with the heart itself.
c. Antacids neutralize hydrochloric acid that is harmful to the stomach lining.
d. Heartburn can usually be relieved by medications that contain base to counteract the excessive acidity.

57) Which of the following food or drinks may worsen heartburn (Choose as many as apply):

a. Beer
b. Carbonated drinks
c. Bottled distilled water
d. Citrus fruits and juices

58) Which of the following medications can be used to treat heartburn (Choose as many as apply):

a. Proton pump inhibitors, like Prilosec OTC, which stop nearly all stomach acid production.
b. Antibiotics, like Penicillins and Ansamycins, which stop growth of bacteria that cause heartburn or kill the bacteria directly
c. H2 blockers, like Pepcid AC, Tagamet, and Zantac, which reduce stomach acid production.
d. Antacids, like Maalox or Mylanta, which help neutralize stomach acid.

59) Which of the following statements is INCORRECT? (Choose as many as apply)

a. The burning sensation of heartburn is resulted from hydrochloric acids contacting the esophageal lining.
b. Any bases can be used to treat heartburn.
c. Physical activity immediately following ingestion of food may exaggerate symptoms of heartburn.
d. The treatment of heartburn is mainly to trigger the secretion of bases in the stomach.

APPENDIX D. Supplementary Tables

Table 22

Item-Level Descriptive Statistics of Epistemic Aims and Mastery Goals

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
Antifreeze								
Mastery Goals								
1	It's important to me that I learn a lot of new concepts from this research.	353	0	100	83.12	21.69	-1.60	2.34
2	One of my goals of doing this research is to learn as much as I can.	354	0	100	85.80	20.44	-1.87	3.55
3	One of my goals is to master a lot of new skills through this research.	354	0	100	78.55	24.87	-1.30	1.00
4	It's important to me that I thoroughly understand the search result.	354	0	100	88.77	18.79	-2.39	6.22
5	It's important to me that I improve my skills through this research.	354	0	100	83.18	22.23	-1.80	3.18

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
6	I want to learn as much as possible from this post about antifreeze.	354	0	100	85.30	19.94	-1.78	3.90
7	It's very important for me to understand the content of the post about antifreeze.	354	0	100	89.87	19.97	-2.17	6.03
8	I desire to completely master the information presented in this post.	354	0	100	85.21	20.30	-1.90	2.13
True Beliefs								
1	I would like to know how much of the information about antifreeze in the post is true	354	0	100	90.70	18.56	-2.71	7.84
2	I would like to know how much of the information about antifreeze in the post is false.	354	0	100	89.76	20.30	-2.53	6.51
3	I would like to get only the true information about antifreeze from the post.	354	0	100	90.47	21.24	-2.79	7.69

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
4	I would like to avoid getting false information about antifreeze from the post.	354	0	100	92.08	19.72	-3.21	10.46
5	I would like to find out what is true about antifreeze in the post.	354	0	100	92.81	16.36	-3.51	14.20
6	I would like to find out what is false about antifreeze in the post.	354	0	100	90.03	20.37	-2.75	7.74
Justified Beliefs								
1	I would like to seek evidence for the information about antifreeze in the post.	354	0	100	82.99	23.45	-1.73	2.56
2	I would like to know some arguments against the information about antifreeze in the post.	354	0	100	79.17	25.51	-1.49	1.65

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
3	I would like to evaluate whether evidence is strong enough to support the information about antifreeze in the post.	354	0	100	82.79	22.62	-1.75	2.91
4	Any evidence would be good enough for me to believe the information about antifreeze in the post. (R)	354	0	100	57.39	34.24	-.14	-1.33
5	I would like to think about the arguments for and against the information about antifreeze in the post.	354	0	100	76.05	26.27	-1.26	1.04
6	I would like to compare and contrast different evidences for the information about antifreeze in the post.	353	0	100	75.89	26.78	-1.25	.91
Explanatory Connection								

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
1	I do not want to understand why it is dangerous to consume antifreeze. (R)	354	0	100	82.27	27.99	-1.65	1.76
2	After reading the post, all I need to remember is the fact that antifreeze is dangerous for human body. (R)	353	0	100	57.76	35.56	-.23	-1.40
3	I would like to grasp how the facts are connected about antifreeze in the post.	354	0	100	82.08	22.13	-1.48	2.03
4	I would like to know the meanings of the terms in the post.	354	0	100	84.79	21.30	-1.86	3.42
5	Regarding the information about antifreeze in the post, I would like to know why things work the way they do.	354	0	100	85.36	21.43	-2.10	4.60
6	I would like to know the explanation for the information about antifreeze in the post.	354	0	100	84.52	21.09	-1.80	3.39

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
Corrosion								
Mastery Goals								
1	It's important to me that I learn a lot of new concepts from this research.	354	0	100	80.36	23.28	-1.65	2.73
2	One of my goals of doing this research is to learn as much as I can.	354	0	100	84.35	22.68	-1.94	3.68
3	One of my goals is to master a lot of new skills through this research.	353	0	100	77.48	24.57	-1.37	1.51
4	It's important to me that I thoroughly understand the search result.	354	0	100	87.96	19.91	-2.56	7.35
5	It's important to me that I improve my skills through this research.	353	0	100	82.39	22.70	-1.72	2.93
6	I want to learn as much as possible from this post about corrosion of iron.	354	0	100	83.53	21.86	-2.04	3.86

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
7	It's very important for me to understand the content of the post about antifreeze.	354	0	100	86.97	19.19	-2.65	7.42
8	I desire to completely master the information presented in this post.	353	0	100	81.32	22.38	-1.76	2.84
True Beliefs								
1	I would like to know how much of the information about corrosion in the post is true	354	0	100	90.78	17.77	-2.60	7.70
2	I would like to know how much of the information about corrosion in the post is false.	354	0	100	89.44	20.37	-2.43	5.95
3	I would like to get only the true information about corrosion from the post.	354	0	100	88.58	24.89	-2.56	5.74
4	I would like to avoid getting false information about corrosion from the post.	354	0	100	92.05	20.41	-3.26	10.47

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
5	I would like to find out what is true about corrosion in the post.	353	0	100	92.88	15.44	-3.22	12.49
6	I would like to find out what is false about corrosion in the post.	354	0	100	88.23	23.28	-2.57	6.19
Justified Beliefs								
1	I would like to seek evidence for the information about corrosion in the post.	354	0	100	82.74	21.91	-1.72	2.95
2	I would like to know some arguments against the information about corrosion in the post.	354	0	100	78.27	24.67	-1.42	1.68
3	I would like to evaluate whether evidence is strong enough to support the information about corrosion in the post.	354	0	100	81.70	23.05	-1.79	3.20

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
4	Any evidence would be good enough for me to believe the information about corrosion in the post. (R)	354	0	100	56.10	32.48	-.05	-1.23
5	I would like to think about the arguments for and against the information about corrosion in the post.	354	0	100	73.93	27.12	-1.17	.77
6	I would like to compare and contrast different evidences for the information about corrosion in the post.	354	0	100	74.84	26.86	-1.22	.87
Explanatory Connection								
1	I do not want to understand why corrosion can be prevented by minimizing the presence of electrolytes and acids. (R)	354	0	100	73.43	30.71	-.98	-.21

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
2	After reading the post, all I need to remember is the fact that corrosion can be prevented in those ways. (R)	354	0	100	59.91	32.60	-.23	-1.19
3	I would like to grasp how the facts are connected about preventing iron from rusting in the post.	354	0	100	82.88	20.65	-1.63	2.95
4	I would like to know the meanings of the terms in the post.	354	0	100	84.16	22.66	-2.00	3.96
5	Regarding the information about corrosion in the post, I would like to know why things work the way they do.	352	0	100	85.84	19.92	-1.96	4.22
6	I would like to know the explanation for the information about corrosion in the post.	354	0	100	84.32	21.43	-1.86	3.62

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
Heartburn								
Mastery Goals								
1	It's important to me that I learn a lot of new concepts from this research.	354	0	100	86.46	19.78	-2.07	4.67
2	One of my goals of doing this research is to learn as much as I can.	354	0	100	87.96	18.88	-2.24	5.37
3	One of my goals is to master a lot of new skills through this research.	354	0	100	80.04	23.76	-1.56	2.15
4	It's important to me that I thoroughly understand the search result.	353	5	100	91.41	14.71	-2.85	10.22
5	It's important to me that I improve my skills through this research.	354	0	100	83.40	22.24	-1.79	3.22
6	I want to learn as much as possible from this post about heartburn.	353	0	100	86.97	18.92	-2.42	5.84

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
7	It's very important for me to understand the content of the post about antifreeze.	354	00	100	89.19	14.17	-2.83	7.17
8	I desire to completely master the information presented in this post.	354	0	100	86.64	19.87	-2.27	4.54
True Beliefs								
1	I would like to know how much of the information about heartburn in the post is true	354	0	100	93.06	15.06	-3.33	13.24
2	I would like to know how much of the information about heartburn in the post is false.	354	0	100	91.30	18.95	-3.00	9.47
3	I would like to get only the true information about heartburn from the post.	354	0	100	91.74	21.14	-3.25	10.21
4	I would like to avoid getting false information about heartburn from the post.	354	0	100	93.12	19.18	-3.69	13.67

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
5	I would like to find out what is true about heartburn in the post.	353	5	100	94.71	12.63	-3.82	17.94
6	I would like to find out what is false about heartburn in the post.	354	0	100	91.99	17.79	-3.06	10.17
Justified Beliefs								
1	I would like to seek evidence for the information about heartburn in the post.	354	0	100	86.34	19.89	-2.14	5.11
2	I would like to know some arguments against the information about heartburn in the post.	353	0	100	81.59	23.80	-1.71	2.66
3	I would like to evaluate whether evidence is strong enough to support the information about heartburn in the post.	352	0	100	84.66	20.64	-1.93	4.13

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
4	Any evidence would be good enough for me to believe the information about heartburn in the post. (R)	354	0	100	55.33	33.92	-.09	-1.26
5	I would like to think about the arguments for and against the information about heartburn in the post.	354	0	100	76.75	25.69	-1.25	1.05
6	I would like to compare and contrast different evidences for the information about heartburn in the post.	354	0	100	77.22	26.08	-1.37	1.31
Explanatory Connection								
1	I do not want to understand why antacids can treat heartburn. (R)	351	0	100	82.14	26.14	-1.64	1.93

Table 22, continued

Domain	Item	*N*	Min.	Max.	*M*	*SD*	Skew.	Kurt.
2	After reading the post, all I need to remember is the fact that heartburn can be treated with antacids. (R)	354	0	100	68.16	31.91	-.57	-.98
3	I would like to grasp how the facts are connected about heartburn in the post.	353	0	100	84.50	21.26	-1.82	3.53
4	I would like to know the meanings of the terms in the post.	354	0	100	86.82	20.67	-2.23	5.22
5	Regarding the information about heartburn in the post, I would like to know why things work the way they do.	353	0	100	89.16	17.73	-2.52	7.43
6	I would like to know the explanation for the information about heartburn in the post.	354	0	100	88.14	17.64	-2.35	7.15

Note. R = Item score reversely coded.

Table 23

Item-Level Descriptive Statistics of Perceived Ability with Sources

Perceived Ability	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Professor's post	354	10	100	93.3	9.83	-2.94	15.9	--													
2. "My" experiment	352	9	100	84.6	11.7	-1.66	6.24	.433[b]	--												
3. Scholarly journal	353	0	100	74.5	16.5	-1.52	3.56	.298[b]	.512[b]	--											
4. Scholar discussion	353	9	100	72.6	17.2	-1.26	1.99	.225[b]	.464[b]	.817[b]	--										
5. Lab report	354	0	100	87.5	11.3	-2.83	16.1	.420[b]	.518[b]	.385[b]	.393[b]	--									
6. Documentary	354	9	100	82.1	13.6	-1.78	5.51	.344[b]	.462[b]	.599[b]	.642[b]	.576[b]	--								
7. Experiment video	354	9	100	86.8	11.6	-2.06	8.17	.394[b]	.451[b]	.530[b]	.572[b]	.579[b]	.719[b]	--							

Table 23, continued

Perceived Ability	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
8. Textbook	354	9	100	86.4	10.8	-1.77	7.79	.435[b]	.510[b]	.511[b]	.488[b]	.509[b]	.486[b]	.573[b]	--						
9. Expert in field	354	9	100	85.3	15	-2.25	6.95	.274[b]	.346[b]	.428[b]	.373[b]	.461[b]	.424[b]	.450[b]	.401[b]	--					
10. Anonymous blog	354	0	100	87.3	13.1	-2.71	12.5	.248[b]	.254[b]	.334[b]	.328[b]	.417[b]	.334[b]	.336[b]	.334[b]	.453[b]	--				
11. Newspaper	352	9	100	81.4	14.2	-1.72	5.43	.332[b]	.432[b]	.584[b]	.579[b]	.469[b]	.675[b]	.547[b]	.552[b]	.578[b]	.476[b]	--			
12. Wikipedia	354	10	100	89.4	11.9	-2.18	7.9	.354[b]	.460[b]	.360[b]	.374[b]	.378[b]	.406[b]	.424[b]	.527[b]	.344[b]	.446[b]	.465[b]	--		
13. Museum website	352	9	100	83.5	14.2	-1.83	5.75	.342[b]	.364[b]	.486[b]	.471[b]	.572[b]	.681[b]	.620[b]	.519[b]	.497[b]	.443[b]	.666[b]	.503[b]	--	
14. Reference book	352	0	100	80	14.7	-1.78	5.08	.322[b]	.424[b]	.563[b]	.542[b]	.552[b]	.600[b]	.605[b]	.584[b]	.407[b]	.364[b]	.602[b]	.431[b]	.769[b]	--

Note. [b] $p < .01$. Min = Minimum. Max = Maximum. Skew = Skewness. Kurt = Kurtosis.

Table 24

Item-Level Descriptive Statistics of Source Beliefs in Domains of Antifreeze, Corrosion, and Heartburn

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Antifreeze																					
Believing																					
1. Professor's post	354	0	100	89.3	17.3	-3	11	--													
2. "My" experiment	354	0	100	74.8	24.7	-1.2	0.99	.239[b]	--												
3. Scholarly journal	353	0	100	88.5	15.8	-2.5	8.82	.374[b]	.428[b]	--											
4. Scholar discussion	354	0	100	79.1	20.8	-1.4	2.19	.395[b]	.423[b]	.468[b]	--										
5. Lab report	354	0	100	46.9	27.7	-0.3	-0.88	.221[b]	.501[b]	.252[b]	.437[b]	--									
6. Documentary	354	0	100	76.9	20.9	-1.2	1.3	.318[b]	.359[b]	.367[b]	.436[b]	.363[b]	--								

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
7. Experiment video	354	0	100	79	20.6	-1.4	2.08	.319[b]	.463[b]	.399[b]	.512[b]	.379[b]	.540[b]	--							
8. Textbook	354	0	100	87.8	17.4	-2.5	7.62	.474[b]	.329[b]	.470[b]	.380[b]	.208[b]	.257[b]	.398[b]	--						
9. Expert in field	353	0	100	84.5	16.9	-1.9	5.01	.485[b]	.239[b]	.332[b]	.424[b]	.222[b]	.477[b]	.349[b]	.349[b]	--					
10. Anonymous blog	354	0	100	33.7	29.5	0.38	-1.05	.151[b]	.201[b]	.079	.274[b]	.500[b]	.272[b]	.282[b]	.079	.165[b]	--				
11. Newspaper	354	0	100	69.2	24.6	-1	0.41	.321[b]	.282[b]	.429[b]	.430[b]	.377[b]	.450[b]	.397[b]	.325[b]	.458[b]	.372[b]	--			
12. Wikipedia	353	0	100	52.8	30.1	-0.4	-0.96	.240[b]	.250[b]	.197[b]	.356[b]	.418[b]	.328[b]	.300[b]	.189[b]	.218[b]	.489[b]	.401[b]	--		
13. Museum website	352	0	100	82.9	18.9	-2	5.23	.340[b]	.274[b]	.466[b]	.309[b]	.237[b]	.390[b]	.416[b]	.428[b]	.389[b]	.201[b]	.550[b]	.313[b]	--	
14. Reference book	353	0	100	84.8	18.8	-2.2	6.08	.472[b]	.202[b]	.379[b]	.407[b]	.315[b]	.324[b]	.388[b]	.608[b]	.409[b]	.231[b]	.405[b]	.329[b]	.501[b]	--
Refuting																					

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Professor's post	354	0	100	76.0	25.0	-1.3	1.2	--													
2. "My" experiment	354	0	100	50.2	29.6	-0.2	-1.0	.357[b]	--												
3. Scholarly journal	352	0	100	78.6	22.3	-1.4	2.0	.497[b]	.207[b]	--											
4. Scholar discussion	354	0	100	69.9	24.8	-1.0	0.4	.426[b]	.320[b]	.593[b]	--										
5. Lab report	354	0	100	34.5	26.9	0.2	-1.0	.181[b]	.651[b]	.124[a]	.319[b]	--									
6. Documentary	352	0	100	65.9	25.5	-0.8	0.2	.374[b]	.326[b]	.419[b]	.481[b]	.318[b]	--								
7. Experiment video	354	0	100	66.7	25.9	-0.9	0.3	.355[b]	.350[b]	.431[b]	.501[b]	.316[b]	.729[b]	--							
8. Textbook	353	0	100	79.9	22.6	-1.6	2.5	.589[b]	.154[b]	.460[b]	.388[b]	.068	.378[b]	.410[b]	--						
9. Expert in field	354	0	100	75.3	22.8	-1.3	1.7	.486[b]	.203[b]	.486[b]	.503[b]	.226[b]	.526[b]	.487[b]	.496[b]	--					

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
10. Anonymous blog	354	0	100	31.3	30.3	0.7	-0.7	.021	.326[b]	.047	.172[b]	.481[b]	.250[b]	.223[b]	-.017	.218[b]	--				
11. Newspaper	354	0	100	63.2	26.3	-0.6	-0.3	.348[b]	.211[b]	.454[b]	.434[b]	.250[b]	.465[b]	.515[b]	.393[b]	.520[b]	.337[b]	--			
12. Wikipedia	353	0	100	45.7	29.2	-0.1	-1.0	.221[b]	.406[b]	.223[b]	.335[b]	.352[b]	.239[b]	.213[b]	.167[b]	.273[b]	.477[b]	.350[b]	--		
13. Museum website	354	0	100	75.5	23.2	-1.4	2.1	.417[b]	.209[b]	.523[b]	.413[b]	.171[b]	.434[b]	.451[b]	.550[b]	.517[b]	.130[a]	.644[b]	.320[b]	--	
14. Reference book	354	0	100	78.1	22.8	-1.5	2.2	.547[b]	.193[b]	.515[b]	.458[b]	.129[a]	.374[b]	.394[b]	.752[b]	.529[b]	.077	.476[b]	.304[b]	.665[b]	--
Corrosion																					
Believing																					
1. Professor's post	354	0	100	90.3	17.2	-3.0	11.0	--													
2. "My" experiment	354	0	100	76.4	25.9	-1.4	1.4	.248[b]	--												

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
3. Scholarly journal	354	5	100	89.9	13.8	-2.2	6.8	.471[b]	.335[b]	--											
4. Scholar discussion	354	0	100	80.7	20.0	-1.5	2.6	.245[b]	.347[b]	.508[b]	--										
5. Lab report	354	0	100	49.2	27.0	-0.4	-0.7	.186[b]	.505[b]	.146[b]	.352[b]	--									
6. Documentary	353	0	100	74.8	23.7	-1.4	1.7	.315[b]	.411[b]	.346[b]	.397[b]	.373[b]	--								
7. Experiment video	354	0	100	80.1	20.8	-1.4	2.1	.255[b]	.442[b]	.353[b]	.449[b]	.363[b]	.583[b]	--							
8. Textbook	354	0	100	88.7	17.0	-2.6	8.9	.428[b]	.240[b]	.479[b]	.317[b]	.195[b]	.362[b]	.357[b]	--						
9. Expert in field	354	0	100	84.9	17.6	-1.9	5.2	.380[b]	.350[b]	.488[b]	.369[b]	.205[b]	.558[b]	.416[b]	.447[b]	--					
10. Anonymous blog	354	0	100	34.3	29.5	0.3	-1.1	.094	.224[b]	.056	.241[b]	.454[b]	.350[b]	.266[b]	.113[a]	.228[b]	--				
11. Newspaper	354	0	100	69.6	24.5	-1.0	0.4	.265[b]	.246[b]	.391[b]	.352[b]	.347[b]	.488[b]	.404[b]	.264[b]	.402[b]	.371[b]	--			

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
12. Wikipedia	354	0	100	53.6	30.5	-0.4	-1.0	.140^{b}	.186^{b}	.163^{b}	.257^{b}	.384^{b}	.462^{b}	.282^{b}	.246^{b}	.238^{b}	.492^{b}	.375^{b}	--		
13. Museum website	354	0	100	85.8	17.2	-2.1	6.0	.407^{b}	.286^{b}	.630^{b}	.377^{b}	.158^{b}	.441^{b}	.349^{b}	.490^{b}	.488^{b}	.174^{b}	.544^{b}	.283^{b}	--	
14. Reference book	354	0	100	86.0	17.5	-2.1	5.9	.436^{b}	.234^{b}	.521^{b}	.296^{b}	.181^{b}	.428^{b}	.320^{b}	.760^{b}	.469^{b}	.191^{b}	.366^{b}	.337^{b}	.604^{b}	--
Refuting																					
1. Professor's post	354	0	100	76.5	24.5	-1.4	1.6	--													
2. "My" experiment	353	0	100	50.4	27.9	-0.2	-0.7	.329^{b}	--												
3. Scholarly journal	354	0	100	77.5	23.4	-1.4	1.7	.552^{b}	.256^{b}	--											
4. Scholar discussion	353	0	100	70.8	25.0	-1.0	0.4	.443^{b}	.289^{b}	.633^{b}	--										

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
5. Lab report	354	0	100	32.8	26.6	0.3	-0.9	.122[a]	.594[b]	.129[a]	.301[b]	--									
6. Documentary	354	0	100	62.1	25.3	-0.6	-0.1	.327[b]	.316[b]	.416[b]	.482[b]	.329[b]	--								
7. Experiment video	354	0	100	65.6	26.2	-0.8	0.0	.342[b]	.339[b]	.421[b]	.410[b]	.356[b]	.537[b]	--							
8. Textbook	354	0	100	80.2	22.3	-1.6	2.8	.649[b]	.191[b]	.581[b]	.452[b]	.119[a]	.403[b]	.442[b]	--						
9. Expert in field	354	0	100	73.8	24.1	-1.3	1.5	.473[b]	.258[b]	.453[b]	.410[b]	.181[b]	.579[b]	.472[b]	.595[b]	--					
10. Anonymous blog	353	0	100	30.1	29.1	0.7	-0.5	.025	.299[b]	.021	.210[b]	.481[b]	.315[b]	.201[b]	.005	.169[b]	--				
11. Newspaper	354	0	100	60.3	26.8	-0.5	-0.5	.337[b]	.273[b]	.399[b]	.403[b]	.244[b]	.530[b]	.448[b]	.381[b]	.471[b]	.299[b]	--			
12. Wikipedia	354	0	100	43.2	29.0	0.0	-1.0	.206[b]	.292[b]	.264[b]	.322[b]	.420[b]	.382[b]	.345[b]	.263[b]	.272[b]	.444[b]	.276[b]	--		
13. Museum website	354	0	100	74.8	23.6	-1.3	1.5	.496[b]	.212[b]	.516[b]	.445[b]	.182[b]	.498[b]	.422[b]	.608[b]	.517[b]	.125[a]	.564[b]	.303[b]	--	

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
14. Reference book	354	0	100	77.0	24.3	-1.5	1.7	.533[b]	.169[b]	.525[b]	.480[b]	.153[b]	.451[b]	.360[b]	.749[b]	.504[b]	.077	.382[b]	.266[b]	.692[b]	--
Heartburn Believing																					
1. Professor's post	354	0	100	89.2	16.8	-2.6	7.9	--													
2. "My" experiment	354	0	100	72.6	26.3	-1.3	1.1	.276[b]	--												
3. Scholarly journal	354	5	100	89.6	13.5	-2.2	7.4	.485[b]	.284[b]	--											
4. Scholar discussion	354	0	100	80.7	19.6	-1.7	3.5	.320[b]	.286[b]	.503[b]	--										
5. Lab report	354	0	100	46.1	28.5	-0.2	-1.0	.180[b]	.528[b]	.152[b]	.290[b]	--									
6. Documentary	353	0	100	77.2	20.4	-1.3	1.8	.287[b]	.426[b]	.361[b]	.470[b]	.341[b]	--								

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
7. Experiment video	354	0	100	78.5	21.1	-1.3	2.0	.231[b]	.450[b]	.342[b]	.478[b]	.397[b]	.592[b]	--							
8. Textbook	354	0	100	88.5	17.0	-2.5	7.5	.551[b]	.414[b]	.496[b]	.285[b]	.234[b]	.424[b]	.374[b]	--						
9. Expert in field	354	0	100	80.4	19.9	-1.6	3.4	.279[b]	.384[b]	.370[b]	.377[b]	.283[b]	.469[b]	.420[b]	.456[b]	--					
10. Anonymous blog	354	0	100	34.7	29.3	0.3	-1.1	.171[b]	.325[b]	.100	.308[b]	.487[b]	.216[b]	.269[b]	.154[b]	.310[b]	--				
11. Newspaper	354	0	100	71.2	23.0	-0.9	0.3	.351[b]	.307[b]	.409[b]	.390[b]	.298[b]	.452[b]	.467[b]	.382[b]	.485[b]	.360[b]	--			
12. Wikipedia	353	0	100	53.6	29.8	-0.4	-1.0	.199[b]	.342[b]	.205[b]	.238[b]	.453[b]	.297[b]	.274[b]	.255[b]	.263[b]	.453[b]	.305[b]	--		
13. Museum website	354	0	100	83.0	18.8	-1.8	4.1	.511[b]	.270[b]	.547[b]	.369[b]	.218[b]	.442[b]	.411[b]	.492[b]	.400[b]	.254[b]	.580[b]	.310[b]	--	
14. Reference book	354	0	100	85.7	17.7	-2.0	5.2	.595[b]	.326[b]	.504[b]	.289[b]	.239[b]	.384[b]	.260[b]	.787[b]	.413[b]	.156[b]	.385[b]	.278[b]	.590[b]	--
Refuting																					

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Professor's post	354	0	100	76.0	23.9	-1.2	1.1	--													
2. "My" experiment	354	0	100	51.3	29.0	-0.2	-0.9	.457[b]	--												
3. Scholarly journal	354	0	100	78.3	21.2	-1.3	1.7	.597[b]	.340[b]	--											
4. Scholar discussion	354	0	100	71.0	24.3	-1.1	0.9	.388[b]	.372[b]	.607[b]	--										
5. Lab report	352	0	100	33.9	27.2	0.3	-0.9	.252[b]	.619[b]	.203[b]	.325[b]	--									
6. Documentary	354	0	100	64.9	25.5	-0.8	0.0	.331[b]	.347[b]	.448[b]	.482[b]	.344[b]	--								
7. Experiment video	354	0	100	67.1	26.2	-0.9	0.3	.371[b]	.461[b]	.525[b]	.497[b]	.382[b]	.643[b]	--							
8. Textbook	353	0	100	80.2	22.7	-1.7	2.6	.586[b]	.329[b]	.648[b]	.461[b]	.239[b]	.476[b]	.539[b]	--						
9. Expert in field	354	0	100	72.1	23.4	-1.1	1.2	.467[b]	.331[b]	.454[b]	.418[b]	.272[b]	.514[b]	.428[b]	.560[b]	--					

Table 24, continued

Sources	*N*	Min	Max	*M*	*SD*	Skew	Kurt	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
10. Anonymous blog	353	0	100	29.8	28.6	0.6	-0.7	.170[b]	.320[b]	.146[b]	.244[b]	.511[b]	.215[b]	.273[b]	.175[b]	.239[b]	--				
11. Newspaper	354	0	100	62.9	26.5	-0.8	-0.1	.427[b]	.335[b]	.463[b]	.380[b]	.347[b]	.448[b]	.521[b]	.501[b]	.546[b]	.407[b]	--			
12. Wikipedia	354	0	100	44.1	30.1	-0.1	-1.1	.259[b]	.313[b]	.220[b]	.290[b]	.413[b]	.253[b]	.305[b]	.285[b]	.256[b]	.445[b]	.371[b]	--		
13. Museum website	353	0	100	74.8	23.5	-1.3	1.5	.465[b]	.299[b]	.569[b]	.392[b]	.230[b]	.485[b]	.503[b]	.702[b]	.575[b]	.226[b]	.601[b]	.333[b]	--	
14. Reference book	352	0	100	77.6	24.4	-1.5	1.8	.588[b]	.265[b]	.583[b]	.423[b]	.210[b]	.375[b]	.405[b]	.775[b]	.449[b]	.202[b]	.459[b]	.342[b]	.677[b]	--

Table 25

Variance-Covariance Matrix for MTMM Models

	Score	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	A_Mastery Goals	0.034											
2.	C_Mastery Goals	0.026	0.040										
3.	H_Mastery Goals	0.023	0.023	0.029									
4.	A_True Beliefs	0.015	0.014	0.011	0.023								
5.	C_True Beliefs	0.011	0.012	0.009	0.015	0.020							
6.	H_True Beliefs	0.009	0.009	0.010	0.014	0.013	0.016						
7.	A_Justifications	0.024	0.022	0.017	0.018	0.014	0.012	0.046					
8.	C_Justifications	0.022	0.024	0.018	0.014	0.015	0.011	0.033	0.045				
9.	H_Justifications	0.019	0.020	0.019	0.013	0.011	0.011	0.033	0.030	0.040			
10.	A_Explanations	0.019	0.017	0.014	0.014	0.010	0.008	0.023	0.020	0.018	0.032		
11.	C_Explanations	0.017	0.019	0.013	0.011	0.011	0.007	0.021	0.023	0.017	0.022	0.030	
12.	H_Explanations	0.015	0.014	0.014	0.012	0.009	0.010	0.018	0.015	0.019	0.020	0.017	0.026

Note. A = Antifreeze. C = Corrosion. H = Heartburn.