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Understanding the Connection Between Epistemic Beliefs and Internet Searching

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Abstract

Within the context of exploring an ill-structured task using the Google search engine, this study examined (a) the connections between general epistemic beliefs and the complexity of learners' knowledge exploration processes (i.e., learning complexity) and (b) the role of activating learners' task-oriented epistemic beliefs (i.e., epistemic activation) in affecting their learning processes. Survey was used to collect participants' general epistemic beliefs, and direct analysis of participants' think-aloud protocols documenting their knowledge exploration processes was conducted to measure their learning complexity. Results revealed positive epistemology-learning relationships in the way that learners with complex epistemic beliefs are more likely to invest efforts in integrating knowledge, building flexible knowledge representations, evaluating information credibility, engaging in inquiry, and being learning-oriented during their ill-structured Internet search activities. Epistemic activation seemed to provide an opportunity for learners to contemplate varying advanced strategies to evaluate the quality of web information, trigger their efforts to search for alternative views during learning, and enhance their awareness of task complexity and subjectivity. In addition, learners with complex epistemic beliefs seemed to benefit more from epistemic activation in terms of using advanced strategies for web information evaluation. This research contributes to (a) theoretical understandings of epistemology in connection to learning complexity when learning

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is open-ended and (b) pedagogical practices of using the epistemic activation strategy to promote deep learning in Internet-based learning environments.

Keywords

epistemic beliefs, deep and complex learning, Internet-based learning, open-ended learning environments, ill-structured knowledge domains

Introduction

Today's society requires that people think critically about problems. Some problems—such as "What is the capital city of the state of Wisconsin?"—are well-structured problems (Kitchener, 1983) that are specific, clearly defined, and have just one correct answer. Other problems are ill structured, such as should we avoid genetically engineered (GE) food, or how does hunting affect a woodland ecosystem. Ill-structured problems can have multiple solutions, are ambiguously defined, and have no inherent correct answer, and oftentimes do not adhere to a single discipline of knowledge with clear-cut boundaries and can be approached by several avenues of investigation.

Learning to solve ill-structured problems requires deep understanding of the issues at hand and balancing multiple perspectives. Learners need to derive their own goals, investigate different cases and alternatives, build connections across information, generate questions, elaborate and justify theories, relate the new information to the real world, and recognize their own biases (Hare, 2003; Marton & Säljö, 2005; Spiro & Deschryver, 2009; Vermunt & Vermetten, 2004).

Now ubiquitous in schools, industries, and personal lives, the Internet represents a powerful learning environment to approach such problems (DeSchryver & Spiro, 2009). Aided by hyperlinks and search engines, Internet users can explore an ill-structured problem by searching expansively for individual cases, counterexamples, and personal stories. After that, they can synthesize them into their existing knowledge structure and reconstruct new ideas. Hypothetically, the Internet is an environment that can nurture complex learning (Jacobson, 2008). Yet, prior studies have documented relatively shallow knowledge exploration in Internet-based learning environments—both K-12 students and university students tend to use the Internet to collect information or to find quick answers, rather than to elaborate, explore, and justify ideas (e.g., Mansourian & Ford, 2007; Wallace, Kupperman, Krajcik, & Soloway, 2000).

Why do students often use the Internet to find quick answers rather than to construct deep understandings? This study explores one potential factor—the role of learners' epistemic beliefs, or beliefs about knowledge and learning—on how Internet searching and learning tasks are conducted.

Previous studies have revealed some connections between learning complexity and personal epistemology in the environment using preprogrammed hypertext systems (e.g., Jacobson & Spiro, 1995; Pieschl, Stahl, & Bromme, 2008; Windschitl & Andre, 1998) and preselected printed materials (e.g., Bråten & Strømsø, 2009; Wineburg, 1991). These experimental learning environments, however, were highly controlled, bounded, and limited. They do not reflect the realities of how learners' beliefs impact their learning in the autonomous, open-ended Internet-based learning of today.

The purpose of the current study, therefore, was to examine the relationship between personal epistemology and learning complexity in a real-world open-ended online environment. Personal epistemology in this study refers to individuals' general beliefs about the nature of knowledge and knowing (e.g., beliefs about whether knowledge is interconnected and beliefs about whether learning is an active process in which learners construct information). Learning complexity in this study refers to the complexity of individuals' learning strategies involved when exploring a complex ill-structured searching task using the Google search engine.

Epistemic Beliefs

Prior studies have focused on five issues that will be discussed in detail.

Views of personal epistemology. Influenced by Perry's (1970) initial work, a *developmental view* considers personal epistemology as an integrated cognitive structure developing from simple to complex stages. Although scholars have adopted different terms in their models (e.g., Baxter Magolda, 1987; King & Kitchener, 1994), Kuhn, Cheney, and Weinstock (2000) proposed that the development of epistemic beliefs shared a general sequence, starting with an *absolutist stage* (i.e., Knowledge is seen to be objective and can be evaluated as true or false. Authorities have knowledge and pass the knowledge to others.), followed by a *multiplist stage* (i.e., Knowledge is seen to be subjective entirely. Truth lies only within the self, and the absolute answer to any question does not exist. All viewpoints are relative and equally valid.), and ended up with an *evaluativist stage* (i.e., Knowledge is seen to be both subjective and objective. Some judgments are more reasonable or valid than others).

During the 1990s, Schommer (1990) introduced a *dimensional view* of personal epistemology. She posited five relatively independent epistemic dimensions: (a) simplicity of knowledge (ranging from the belief that knowledge is isolated and simple to the belief that knowledge is interrelated and complex), (b) certainty of knowledge (ranging from the belief that knowledge is absolute to the belief that knowledge is tentative), (c) speed of learning (beliefs about whether learning occurs quickly), (d) implicit ability (beliefs about whether the ability to learn is innate), and (e) source of knowledge (a continuum from the view that knowledge is from authority to the view that knowledge is derived from reasoning).

Both developmental and dimensional perspectives have been challenged. Researchers supporting dimensional views questioned the unitary construct of personal epistemology held by developmental psychologists, whereas researchers with dimensional views cannot agree on specific dimensions. Other dimensions have been identified and validated, including flexibility of knowledge and learning (Spiro, Feltovich, & Coulson, 1996); regulatory perspective of learning; and justification for knowing (Hofer, 2004). In addition, a lot of empirical data (e.g., Hofer, 2000; Nussbaum & Bendixen, 2003; Qian & Alvermann, 1995) have shown significant interrelationships across epistemic dimensions. Therefore, researchers (e.g., Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008) tend to assume that personal epistemology is an integrated construct including several interrelated epistemic dimensions, and this assumption was used to guide the measuring process of epistemic beliefs in this study.

Contextual factors. Early studies of personal epistemology have focused on its contextually independent nature (e.g., King & Kitchener, 1994; Perry, 1970; Schommer, 1990), assuming that general epistemic beliefs serve as a core basis from which contextually based epistemic beliefs derive (Schommer-Aikins, 2002). Subsequently, epistemic beliefs have been investigated within specific domains (Buehl & Alexander, 2005; Kuhn et al., 2000), assuming that as individuals gain more expertise in one domain, they are likely to form a coherent conception of knowledge and knowing within that domain (Limón, 2006). Recent studies have found that epistemic beliefs even differ across specific contexts in the same domain (e.g., diSessa, Elby, & Hammer, 2003; Leach, Millar, & Ryder, 2000; Louca, Elby, Hammer, & Kagey, 2004), which triggers investigating the role of contextualized personal epistemology on learning (Hofer, 2004; Mason, Boldrin, & Ariasi, 2010).

Researchers, however, cannot agree on the nature of what context-specific epistemic beliefs to measure and how to cleanly separate context-specific epistemology from the general epistemology or learning strategies (Elby, 2009; Sandoval, 2009; Schommer-Aikins, 2004). Indeed, the idea of even measuring what makes the context specific is complicated. As Schommer-Aikins (2004) pointed out, the contextualized epistemic beliefs measured through existing methods are confounded by various learning factors, such as learning topics, learning materials, and learners' prior knowledge. Therefore, it is not surprising that many studies (e.g., Hofer, 2004; Mason et al., 2010; Whitmire, 2003) have discerned the positive correlation between contextualized epistemic beliefs and learning. In addition, considering the unlikelihood of replicating an identical learning context, the studies on contextualized epistemic beliefs may have very limited implications. Thus, this study was designed to investigate the relationship between general epistemic beliefs and learning on the Internet.

Measuring general epistemic beliefs. Two methods have been widely used to collect general epistemic beliefs: interviews (e.g., King & Kitchener, 1994; Perry, 1970) and surveys (e.g., Germer, Efran, & Overton, 1982; Jehng, Johnson, & Anderson, 1993; Schommer, 1990; Schraw, Bendixen, & Dunkle, 2002; Schraw, Dunkle, & Bendixen, 1995; Spiro et al., 1996; Wood & Kardash, 2002). The interview method requires training coders, and thus, is subjective to some extent. Schommer (1990) developed a survey, called the *Schommer Epistemological Questionnaire* to measure general epistemic beliefs through the five dimensions she proposed. Schraw et al. (1995, 2002) validated a short version, the *Epistemic Beliefs Inventory* (EBI), to measure Schommer's five dimensions. Meanwhile, Kuhn et al. (2000) developed a survey measuring the developmental stages of epistemic beliefs in different domains, from *absolutists to evaluativists*. Although these three surveys have been widely used in the field, the *Schommer Epistemological Questionnaire* and the EBI do not include items measuring the knowledge justification dimension (Hofer, 2004) that is activated frequently during the learning process using Internet search engines (Mason et al., 2010). Most importantly, these three instruments do not include the items specifically measuring the flexibility of knowledge and learning dimension (Spiro et al., 1996) that is crucial in ill-structured knowledge domains and pertinent to this study.

In 1996, Spiro et al. validated an inventory, called the *Cognitive Flexibility Inventory* (CFI), "assessing beliefs and preferences about learning as these relate to advanced knowledge acquisition in complex domains" (p. S52). This instrument was aimed to distinguish individuals with two types of "epistemic world-views" (p. S55). On the one end, individuals with reductive worldviews consider knowledge as "a single representation of complex phenomena" (p. S55), integrate knowledge through an additive process, "assume the world to be fundamentally orderly" (p. S55), assume simplicity of learning, and believe learning is a process of passively receiving knowledge. On the other end, individuals with expansive and flexible worldviews perceive knowledge as multiple representations of complex phenomena, recognize the importance of interactions among parts of complex phenomena, "assume the world to be fundamentally disorderly" (p. S58), assume complexity of learning (e.g., knowledge is not black or white, is contextually based, and can be ambiguous), and believe learning is a process of actively constructing knowledge. Spiro et al. (1996) believe that individuals with reductive worldviews can do well in well-structured knowledge domains, but they are poorly suited in ill-structured knowledge domains that require complex and contextually based knowledge acquisition. This instrument, pertaining to the context of this study, was considered as an option to measure general epistemic beliefs in this study.

Activating epistemic beliefs. The epistemology collected through the survey method measures individuals' professed (i.e., stated) epistemic beliefs (Limón, 2006), and there is a concern that collecting professed epistemic beliefs can prime participants to be more cognizant of their epistemology, which may change their learning processes (Louca et al., 2004). Priming effect can be more salient if it is enacted right before learning by raising learners' metacognitive awareness of their epistemic beliefs (Hofer, 2004), possibly leading them to recognize the complexity of the given task that they may not consider otherwise (Schraw, 2000).

On the other hand, because the priming effect can change the subsequent learning process, it is interesting to understand how this happens. Studies have shown that stimulating individuals to reflect on some metacognitive prompts each time they are exposed to new learning materials during the learning process can result in more complex learning (Bannert, 2006; Demetriadis et al., 2008). Because epistemic thinking operates at metacognitive levels (Hofer, 2004), it is reasonable to assume that presenting task-oriented epistemic prompts to activate learners' epistemic awareness during learning can enhance learning complexity. Nevertheless, it is not very practical for classroom teachers to ask their students to contemplate epistemic prompts each time when a new learning material is presented, especially when students learn at their own pace on the Internet. Yet, the effect of prompts presented prior to learning has not been investigated. If contemplating these prompts prior to learning results in a greater extent of complex learning, this approach may be of considerable value to teachers.

Scholars also believe that if individuals are aware of their epistemic beliefs, their influence on learning may be magnified (e.g., Kitchener, 1983; Muis, 2007). Therefore, they suggest activating learners' personal epistemology through proposing prompts before learning to strengthen the epistemology-learning connection (Kitchener, 1983). This assumption, however, has not been tested empirically. When individuals search the Internet to explore an ill-structured task, they may spontaneously activate some dimensions of their epistemic beliefs. For instance, in Mason et al.'s (2010) study, two epistemic dimensions, source of knowledge (i.e., whether the knowledge exists externally or within individual learners) and knowledge justification process (whether learning is to accept authoritative information or to make meaning from the external information), were activated frequently during their learning processes. But only a few participants reflected on the simplicity of knowledge and the certainty of knowledge dimensions. Thus, although there is some evidence disclosing the spontaneous arousal of epistemic thinking, constructing epistemic prompts that can trigger comprehensive epistemic thinking is important.

Epistemology and learning. Prior studies have revealed potential epistemology-learning relationships in varying environments. Complex thinkers (i.e., learners with complex epistemic beliefs) are more likely to (a) benefit from the case-based hyperlink learning environment in which the interconnections among cases are accentuated (Jacobson & Spiro, 1995; Windschitl & Andre, 1998); (b) integrate knowledge across multiple sources (e.g., Barzilai & Zohar, 2012; Bråten & Strømsø, 2006b, 2009); (c) conceive themselves capable of critiquing and assessing web information and being open to conflicting arguments (Whitmire, 2003); (d) engage in learning-oriented Internet communications (Bråten & Strømsø, 2006a); (e) favor the learning environment facilitating inquiry and reflective thinking (Tsai & Chuang, 2005); and (f) process more pages in hypertext systems (Pieschl et al., 2008). On the other hand, some studies have shown no or negative epistemology-learning relationship (e.g., Barzilai & Zohar, 2012; Bråten, 2008), demanding more investigations on how personal epistemology relates to learning.

When investigating epistemology-learning relationship, it is important to focus on learning processes. Personal epistemology addresses such issues as how learners think about knowledge and knowing; *how* they approach a problem; and *how* they select, evaluate, and integrate information. In short, understanding the role personal epistemology on learning is to study learning processes, not learning outcomes. Of course, learning processes lead to learning outcomes (Marton & Säljö, 2005). But, essential investigations should focus on learning processes.

Learning in Complex Tasks

To examine the role of epistemology on the complexity of knowledge exploration in open-ended Internet-based environments, finding markers of complex and less complex learning strategies in this new research domain is a tough task. However, previous research on learner approach to searching tasks or to process ill-structured tasks can be used.

Some factors impacting search performance. Four factors that may affect Internet-based learning have been identified in prior studies, and its influence should be controlled when investigating epistemology-learning relationships:

- *Prior content knowledge*—helps learners to form better searches and evaluate the trustworthiness of information sources (Bråten, Strømsø, & Salmerón, 2011; Palmquist & Kim, 2000; Wildemuth, 2004).
- *Verbal comprehension*—helps learners process the text more readily and relates to general intellectual ability (Qian, 2002; Stanovich, 2000).
- *Effort*—Effort investment impacts learning processes (Boekaerts & Cascallar, 2006).
- *Time on task*—Learners who spend more time learning demonstrate better performance (Garfield, 1995).

Complex learning strategies. Although there are a numerous ways to categorize learning strategies, a number of learning strategies emerged from the literature on open-ended learning in complex and ill-structured domains.

– *Building knowledge connections*. An important feature of complex and deep learning in ill-structured domains is to build knowledge connections, rather than to accumulate facts (Rouet, 2006; Wallace et al., 2000). For example, to find new information or conduct a new search, learners have to call on prior content knowledge (or prior search results) to craft new search terms (Bilal, 1998; Wildemuth, 2004), compare the new information with other resources, and synthesize that information into existing knowledge to form a coherent knowledge representation (Barzilai & Zohar, 2012). Learners, therefore, may differ on the extent of knowledge integration.
– *Building flexible understanding*. Complex knowledge exploration includes the idea that learners flexibly assemble their knowledge (Spiro & Deschryver, 2009) and stay open-minded (Hare, 2003). Complex learners ask questions such as, "What is the author's purpose for proposing this argument?" and attempt to interpret an issue through multiple lenses (Spiro et al., 1996), and such learners are less likely to hold a one-size-fits-all conclusion.
– *Evaluating web information*. Learners conducting search on the Internet often have to evaluate the quality of web information (Kammerer, Bråten, Gerjets, & Strømsø, 2013; Rouet, Ros, Goumi, Macedo-Rouet, & Dinet, 2011; Strømsø, Bråten, Britt, & Ferguson, 2013). Most simply, learners evaluate URLs, the identity of authors, and the recentness of web information (Eagleton & Dobler, 2007). More advanced strategies involve learners' evaluation of the content per se, with regard to such things as (a) writing quality; (b) providing evidence in the form of references; (c) data triangulation; and (d) the quality of evidence, the flow of arguments, and logical reasoning (Zhang, Duke, & Jiménez, 2011).
– *Engaged in inquiry*. Internet searches offer learners a chance to bring their own ideas, questions, and interpretations to the table (DeSchryver & Spiro, 2009). Taken to the extreme, of course, these can be considered a distraction as learners get taken off course exploring hyperlinks (Scheiter & Gerjets, 2007). Yet, in open-ended learning environments in which learning goals are not restricted, these are instances of learners' active interaction with the text (Graesser, McMahen, & Johnson, 1994; King, 1994), and thus, indicated complex knowledge exploration (Marton & Säljö, 2005; Vermunt & Vermetten, 2004).
– *Setting and completing goals*. Guiding oneself through a complex Internet search task requires tapping into ones' interest, to generate learning goals such as new questions or issues to explore (DeSchryver & Spiro, 2009). It also requires that learners use metacognitive strategies to remind themselves of these goal structures (such as mental reminders), as well as to monitor their progress on the goals (Marton & Säljö, 2005).

Summary and Importance

Prior studies have shown inconsistent relational patterns between personal epistemology and different learning strategies (e.g., Barzilai & Zohar, 2012; Bråten, 2008; Bråten & Strømsø, 2009; Pieschl et al., 2008). Hartley and Bendixen's (2001) call for studying epistemic beliefs in the Internet-based learning environment triggered observations of epistemic beliefs in practice (e.g., Hofer, 2004; Mason et al., 2010). Yet, epistemic thinking in practice is usually confounded by various contextual factors, and thus, may not demonstrate sufficient evidence on whether learning processes relate to epistemic beliefs that are independent from the contexts (Schommer-Aikins, 2004). Moreover, some researchers (e.g., Tsai & Chuang, 2005; Whitmire, 2003) studying the epistemology-learning relationship measured perceived learning processes (through self-report instruments), but learning processes need to be measured through direct observations (Bråten, 2008). Finally, researchers suspected a positive role of epistemic activation (in this study, epistemic activation refers to providing participants with prompts that can trigger their epistemic thinking centered upon the given Internet search task) prior to learning (Kitchener, 1983; Muis, 2007). Yet, this assumption has never been tested.

Purpose and Research Questions

The purpose of this study was to investigate the relationship between general epistemic beliefs and the complexity of learners exploring a complex ill-structured searching task using the Google search engine. This study also investigated the impact of *activating* task-oriented epistemic beliefs, referring to a process whereby prior to the start of the searching task, some participants (randomly assigned) were asked to reflect on their epistemic beliefs targeted at the given Internet search task through prompts.

Learners' approach to the searching task operates as the *complexity of learning processes* (*or learning complexity*), defined as the extent to which learners engage in the complex learning strategies of (a) Building knowledge connections, (b) Building flexible understanding, (c) Evaluating web information, (d) Being engaged in inquiry, and (e) Setting and completing goals.

Three research questions were explored:

1. What is the relationship between participants' general epistemic beliefs and the complexity of their learning processes?
2. What is the impact of activating participants' task-oriented epistemic beliefs prior to learning on the complexity of their learning processes?
3. Can epistemic activation prior to learning strengthen the epistemology-learning connection?

Method

Participants

Fifty-three undergraduate students from a Midwestern university voluntarily participated in this study. There were 32 females and 21 males, with ages ranging between 18 and 26, with a mean of 20.19 ($SD = 1.70$). Forty-one were Caucasian (non-Hispanic), five African American (non-Hispanic), one Hispanic or Latino, three Asian or Pacific Islander, and three biracial or multiracial. Participants included 10 freshmen, 12 sophomores, 21 juniors, and 10 seniors.

Materials

Ill-structured task. The ill-structured Internet search task adopted in this study asked participants to use the web to form and validate their own views on whether GE crops are safe to eat. There was no time limit, and participants could stop whenever they felt satisfied with their learning and confident that their views were well supported. Without imposing a time limit, participants were able to explore the task as thoroughly as they wanted. Participants could take notes while exploring the task if needed, but note-taking was not required.

Epistemic prompts. Five epistemic prompts (see Appendix A) were composed to prime participants in the activation condition to reflect on their epistemic beliefs prior to undertaking the ill-structured task. The prompts were written based on the given task and included five hypothetical scenarios that participants may encounter when exploring the task. Participants in the activation group responded to all prompts and submitted their responses online. The prompts were used to prime participants to be aware of their epistemic beliefs regarding the given topic, rather than to change participants' epistemic beliefs.

As stated in the literature, scholars in the field cannot reach an agreement on what specific epistemic dimensions should be included. Therefore, the challenge of designing the prompts in this study was to compose a reasonable number of questions covering important epistemic dimensions that might be pertinent to the context of this study. We aimed to activate six epistemic dimensions: (a) context dependency of knowledge (Spiro et al., 1996); (b) simplicity of knowledge (Hofer, 2004; Schommer, 1990); (c) certainty of knowledge (Hofer, 2004; Schommer, 1990); (d) source of knowledge (Hofer, 2004; Schommer, 1990); (e) justification for knowing (Hofer & Pintrich, 1997); and (f) regulatory perspective of learning (Hofer, 2004).

The composed prompts were tested through a pilot study on nine undergraduate participants. Analysis of responses showed that (a) two participants activated simplicity of knowledge (i.e., their responses reflected their epistemic stands on either knowledge is discrete or interconnected. For instance, one participant responded to the second question by saying, "if I do find this [opposing information across reputable websites], I do need to compare them by examining different factors that can lead to the inconsistency." Because this response reflected his epistemic beliefs that knowledge is not discrete and can be interconnected, we knew that this participant's epistemic stance regarding the simplicity of knowledge dimension was activated when he worked on the question); (b) five participants activated certainty of knowledge; and (c) all participants activated the rest of the epistemic dimensions. The results were consistent with Mason et al.'s (2010) and Hofer's (2004) studies in which the majority of their participants was able to spontaneously activate the source of knowledge and the justification for knowing dimensions, whereas only a few participants reflected on the simplicity of knowledge and the certainty of knowledge dimensions during the Internet-based learning processes. Because the goal of epistemic activation in this study was to spontaneously activate, rather than to intentionally manipulate, participants' task-oriented epistemic beliefs, the outcome from the pilot study did reflect the nature of spontaneous epistemic activation.

Instruments and Measures

The revised CFI. The CFI (Spiro et al., 1996) was adopted to collect participants' general epistemic beliefs. As stated in the literature review, this inventory was designed to measure personal epistemology in ill-structured domains (Spiro et al., 1996). A pilot test was also conducted (on 10 undergraduate students) to select the appropriate instrument. In this pilot test, we compared epistemic scores from three instruments: the EBI (developed by Schraw et al. to measure Schommer's five dimensions), Kuhn et al.'s instrument, and the revised CFI (the original CFI was revised, and see more information in the next paragraph). The revised CFI yielded a wider range of epistemic scores, compared with the EBI; and when evaluating the results of Kuhn's instrument, there was only one participant (out of 10) fitting in the absolutist stage in the physical domain (and no absolutist in other domains). Meanwhile, the revised CFI was highly correlated with the EBI ($r = .85$, $n = 10$, $p < .01$). Therefore, the revised CFI was used in this study.

The original CFI includes 15 pairs of conflicting statements, asking participants to rate each statement in a 7-point Likert scale. The CFI in this study (see Appendix B) was revised in three ways: (a) the statements were simplified to fit undergraduate students' reading comprehension; (b) the two opposing statements in each pair stood at the ends of a continuum, and participants were asked to weigh them along a 6-point Likert scale; and (c) the first two pairs of statements in the original CFI were combined due to their similarity; and thus, the revised CFI contained 14 pairs of statements. The revised CFI was tested on 11 undergraduate students to ensure the readability and the accuracy of comprehension.

As discussed in the literature review, we view personal epistemology as a holistic structure composed of multiple interrelated dimensions. Therefore, an overall CFI score was used to measure general epistemic beliefs in this study. The overall CFI score was derived by averaging each of the 14 responses (each on a 1 to 6 scale). Higher scores indicate more complex epistemic beliefs. The observed internal consistency was .69.

Prior content knowledge test. Fourteen true or false questions and an open-ended question were composed to test participants' prior content knowledge about the given topic (see Appendix C), and this construct was treated as a covariate in statistical analyses. The prior content knowledge score was the total number of participants' correct responses to the true or false questions and the number of correct concepts in participants' responses to the open-ended question. Participants' prior content knowledge was not correlated with their general epistemic beliefs ($r = .09$, $p = .54$, $n = 53$).

Learning time. The time in minutes participants spent conducting their learning task was used as a covariate in this study. This variable was not correlated with general epistemic beliefs ($r = .12$, $p = .40$, $n = 53$)

Verbal comprehension test. An 8-min version of Advanced Vocabulary Tests I and II (36 items in total) from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, & Harman, 1976) were used to measure participants' verbal comprehension abilities and treated as a covariate. The Cronbach's alpha for Test I was .53 in Barchard's (2003) study, and the split-half reliability (corrected with the Spearman–Brown prophecy formula) for Test II was .89 in Hirumi and Bowers' (1991) study. Participants' *verbal comprehension* was computed as the sum of their correct answers on the combined 36 items, and it was not correlated with general epistemic beliefs ($r = .13$, $p = .35$, $n = 53$)

Effort survey. This survey (see Appendix D) containing three 7-point Likert scale items was designed to measure participants' perceived effort investment in knowledge exploration. The averaged score was treated as a covariate, and it was not correlated with general epistemic beliefs ($r = .05$, $p = .71$, $n = 53$). The internal consistency (Cronbach's alpha) was .69.

Complexity of learning strategies. Using an alternative think-aloud procedure (see Procedures section), participants justified each action during the search activity. Prior to coding, data were segmented based upon shifts in action (Jordan & Henderson, 1995), such as searching or reading a web page.

The raw data were coded into categories with the codes derived from a combination of a priori (developed in a pilot study) and grounded theory approaches. The resulting final table of categories and codes are presented in Table 1.

Table 1. Coding Categories to Analyze the Complexity of Learning Processes.

Category	Codes	
Building knowledge connections	+ Recalled info from search	+ Synthesized knowledge
	+ Recalled prior knowledge	+ Followed hyperlink
	+ Compared pieces of knowledge	+ Connected through specific reference
Building flexible understanding	+ Investigated contextual meanings	– Avoided a case*
	+ Engaged in rethinking	+ Pursued a case*
	+ Constructed provisional understanding*	+ Pursued alternative*
	– Intolerance of ambiguity*	– Avoided alternative*
	+ Tolerance of ambiguity*	+ Searched for biased arguments*
Evaluating web information	Basic strategies:	Advanced strategies:
	+ Evaluated source	+ Evaluated via triangulation
	+ Evaluated recentness	+ Evaluated citations
		+ Evaluated quality of writing
		+ Evaluated reasoning
		+ Evaluated universal bias*
		+ Evaluation was contextual
		+ Reminded themselves about bias
Engaging in inquiry	+ Brought in new ideas	+ Generated new questions/hypotheses
	+ Made new inferences	
Setting and completing goals	+ Took notes for later exploration	– Focused on an outcome goal*
	– Took notes for recordkeeping	+ Explored a personal interest*
	+ Identified issues to explore	
	+ Explored issues identified	

Note.+ indicates a code associated with more complex learning strategies. – indicates a code associated with less complex learning strategies.
*indicates a code that categorical (either present or not); other codes are treated as frequencies.

Each segment could have multiple codes. An example of how some codes were applied to the think-aloud protocols is shown in Table 2 (please contact the first author for detailed examples of each code). A second coder randomly selected and coded 11 (out of 53) participants' think-aloud protocols, and the interrater agreement was 85.09% (see Zhang, 2011 for the process of calculating the agreement). Coding differences were reanalyzed and resolved by consensus, sometimes resulting in minor adjustments to the coding categories. The remaining data were coded by the first author. The first author also coded all think-aloud protocols twice (4 month apart); and the test-retest agreement was 84.63%. When inconsistency across times happened, the first author reviewed her coding at both times and made a final decision.

After assigning codes to the think-aloud protocols, each of the codes in Table 1 without an asterisk was counted based on occurring frequency for each participant. For example, one participant may have *Recalled info from search* four times during his or her learning process (then, his or her raw score for this code was 4), while another may have done so seven times (then, his or her raw score for this code was 7). On the other hand, codes with an asterisk in Table 1 were coded as qualitative distinctions, indicating a participant displayed the behavior at some point (coded as 1) or not (coded as 0). For example, a participant assumed that everyone or all web information was biased to some extent believed about universal bias (i.e., the *Evaluated universal bias* code). Thus, this participant would have 1 as his or her raw score for this code, no matter how many times he or she verbalized it during their learning processes.

After obtaining raw scores for each participant, raw scores (including dichotomous and frequency counts) were converted to z scores so that they were equally weighed. Composite scores were created for each of the five categories in Table 1 and for the overall learning complexity, by averaging the z scores of the enclosed codes in each category (e.g., the composite score for the *Building Knowledge Connections* category was calculated by the sum of the z scores of its enclosed six codes divided by six). In addition, *Evaluating web information* included two subcategories—participants' adoption of basic strategies and advanced strategies. Thus, the composite scores for each subcategory were constructed as well.

Retrospective interview. Participants were also interviewed following the search activity about their search behaviors and learning processes (see Appendix E). The main goal of this retrospective interview was to corroborate the results from direct analyses of participants' think-aloud protocols. The first author coded interview protocols by implementing codes in Table 1.

For each code in Table 1, the consistency refers to the situation when a learning strategy was identified or not identified in both types of protocols (i.e., think-aloud and interview protocols) and was quantified by the percentage of the participants showing such consistency among all participants (see Table 3).

Table 2. An Example of Coding Think-Aloud Protocols.

Coding segment	Codes assigned	Notes
[reading . . . "health concerns"] "such as toxic and allergic reactions, despite the assurances of the united states government dept. of commerce, the national academy of science, and the FDA, there is no danger". . . .So I am thinking about names of these organizations. FDA, which I have seen already on the search. So reinforces that I should look into what they have to say about the issues. [he then jotted down "FDA"]	Recalled info from search Took notes for later exploration Identified issue to explore	The participant, while reading the web information, recalled that the FDA had been viewed multiple times, so *Recalled info from search* was assigned. Then, he identified that FDA's views should be studied later (i.e., *Identified issue to explore*), and thus, he wrote down FDA to remind himself (i.e., *Took notes for later exploration*).
. . . [keep on reading the same webpage] "However, there are GMOs produced naturally." I don't know what that means. Unless they are talking about what I wrote down earlier—selective breeding. But I don't know because my understanding is it [selective breeding] did not follow under the category of genetic modification.	Synthesized knowledge	Now the participant was trying to understand the relationship between selective breeding and genetic modification, rather than simply recall "selective breeding." Thus, *Synthesized knowledge* was assigned.
. . . [keep on reading the same webpage] So I don't see in this [paragraph, the author discussed] what types of food cause this, how the *E. Coli* spread, and I still feel like this whole bacterium issue might just be related to the food, food poisoning, rather than GE foods specifically, and I'd like to find a very specific case, very specifically of genetic engineering directly related to allergic issue.	Pursued a case	Now the participant expressed that he would like to find out and investigate a specific case. Thus, *Pursued a case* was assigned.

Note. FDA = Food and Drug Administration; GE = genetically engineered; GMOs = genetically modified organisms.

Table 3. Triangulating the Results of the Interview Protocols and the Think-Aloud Protocols.

Codes	Consistency (%)	Inconsistency (%)
Recalled info from search	95.65	0
Recalled prior knowledge	30.43	0
Compared pieces of knowledge	80.43	6.52
Synthesized knowledge	41.30	0
Followed hyperlink	82.61	0
Connected through specific reference	78.26	0
Investigated contextual meanings	63.04	6.52
Constructed provisional understanding	76.09	2.17
Engaged in rethinking	84.78	4.35
Intolerance of ambiguity	86.96	6.52
Tolerance of ambiguity	91.30	2.17
Pursued alternative	80.43	15.22
Avoided alternative	91.30	2.17
Searched for biased argument	73.91	2.17
Avoided a case	91.30	0
Pursued a case	69.57	10.87
Evaluated source	95.65	2.17
Evaluated recentness	82.61	4.35
Evaluated citations	71.74	4.35
Evaluated via triangulation	69.57	8.70
Evaluated quality of writing	65.22	2.17
Evaluated reasoning	78.26	0
Evaluated universal bias	71.74	4.35
Evaluation was contextual	60.87	0
Reminded themselves about bias	47.83	0
Brought in new ideas	NA	NA
Made new inferences	NA	NA
Generated new questions/hypotheses	47.83	0
Indentified issues to explore	NA	NA
Explored issues identified	41.30	0
Took notes for later exploration	NA	NA
Took notes for recordkeeping	NA	NA
Focused on an outcome goal	82.61	4.35
Explored a personal interest	91.30	2.17

Note. NA = no participant reported the corresponding instances during the interview.

Although high consistencies are preferred, low consistencies are not always problematic. Inconsistency happened in two situations. First, during the interview, participants might not recall certain learning strategies they executed when they explored the task, if the interview questions did not cover all learning strategies or the Internet search activity was very long. Some learning strategies may be hard to recall. This type of inconsistency, therefore, was of less concern.

Inconsistency also existed when participants recalled certain learning strategies during the interview, which were not identifiable in their think-aloud protocols. Such inconsistencies could indicate problems of coding think-aloud protocols. The percentage of the participants with such inconsistencies out of all participants was calculated for each code in Table 3 to indicate the inconsistency between two types of data. When participants demonstrated such inconsistencies, their think-aloud protocols were reviewed again to increase the coding reliability.

Procedures

Participants were randomly assigned to one of the two groups: nonactivation (the control group, 26 participants) and activation (27 participants) of task-oriented epistemic beliefs through prompts prior to learning. Participants in both groups had same scores of general epistemic beliefs, $t(51) = 0.52$, $p = .61$. Each participant completed two lab sessions (see Table 4).

During the first lab session, all participants completed the prior content knowledge test. Then, participants in the activation group completed the 8-min version of Advanced Vocabulary Tests I and II. Training on Google search techniques was provided at the end of this session to all participants, and lasted, on average, for 15 min.

During the second session (2 weeks later), the experimenter spent 5 to 10 min with each participant to review the Google search techniques. Then, the experimenter provided a training on an alternative approach of think-aloud protocols used in this study. Initially, we planned to use the traditional think-aloud protocol proposed by Ericsson and Simon (1993). A pilot study on 11 undergraduate students revealed that even after a training session, participants failed to provide sufficient rationales behind their Internet search decisions, which constituted the most important data for identifying learning strategies.

Given this problem, an alternative think-aloud approach was developed. When a participant used the Internet to explore the given problem, an experimenter sat next to him or her and held the mouse. The participant told the experimenter what he or she wanted to do next and explained his or her rationale before the experimenter executed the action. Awareness that this design could alter participants' learning processes, a training session was provided before the Internet search activity to diminish this possibility. During training, the experimenter explicitly stated what to verbalize and stressed that participants would

Table 4. Design and Procedures of the Study.

	Nonactivation group $n = 26$	Activation group $n = 27$
Session 1 (20–35 min)	1. Prior content knowledge test 2. Search training	1. Prior content knowledge test 2. Vocabulary comprehension test (8-min version) 3. Search training
Session 2 (2 weeks later; 2.5 hr)	1. Search review 2. Think-aloud practice 3. Verbal comprehension test (8-min and 12-min version) 4. Searching task 5. Effort survey 6. Interview 7. Revised Cognitive Flexibility Inventory	1. Search review 2. Think-aloud practice 3. Epistemic activation using prompts 4. Searching task 5. Effort survey 6. Interview 7. Revised Cognitive Flexibility Inventory

direct the experimenter and embraced complete control of their learning processes. The experimenter also stressed that if participants did not have perceived rationales for their actions, they should say so. Then, participants practiced the think-aloud process with the experimenter on a preselected topic. The practice was videotaped and immediately played back to participants. Watching their own practice helped participants better understand what to report. This procedure was repeated until participants (a) got used to verbalization and were not aware of their artificial efforts to think aloud anymore and (b) felt comfortable with sitting side by side with the experimenter and demonstrated fluency directing the experimenter while providing rationales. Practice sessions lasted between 20 and 30 min.

The second session then continued with the participants in the activation group contemplating and responding to the epistemic prompts online. No question could be skipped. There was no time limit to address the prompts, but the estimated time was 20 min based on a pilot study. To control for differences in time on tasks between groups, the participants in the nonactivation group completed two sets of vocabulary tests (20 min in total) before exploring the given task. Yet, only the 8-min version of Advanced Vocabulary Tests I and II completed by all participants (in both groups) were scored and used in analyses. Both groups then engaged in the searching task, using the alternative think-aloud procedure explained earlier. Upon finishing the task, all participants completed the effort survey, the retrospective interview, and the revised CFI.

Data Analysis

Hierarchical multiple regression was used to uniquely determine the amount of variation in learning complexity that can be attributed to general epistemic beliefs, task-oriented epistemic activation, and the interaction between these two factors.

Four steps (models) were used in the hierarchical multiple regression, each using the overall learning complexity score and its five dimensional scores as the dependent variables. In addition, we also calculated scores of participants' adoption of basic strategies versus advanced strategies to evaluate web information (i.e., *basic strategies* and *advanced strategies* under the *Evaluating web information* dimension), and these two scores were also treated as the dependent variables. In *Step 1*, all covariates (e.g., time, verbal comprehension, effort, and prior knowledge) were entered. In *Step 2*, general epistemic beliefs (CFI scores) were entered. In *Step 3*, the dichotomous group variable (activation vs. nonactivation) was entered. In *Step 4*, an interaction term between general epistemic beliefs and the group variable was entered.

Results and Discussion

Descriptive results are presented in Tables 5 and 6.

Table 5. Means and Standard Deviations for All Study Measures by Group (Activation vs. Nonactivation).

	Activation group		Nonactivation group	
Measure	*M*	*SD*	*M*	*SD*
Covariates (Control)				
Prior knowledge	7.22	3.03	7.15	2.46
Verbal comprehension	16.30	6.82	16.00	3.87
Time	71.78	25.41	69.92	27.41
Effort	5.90	0.60	6.22	0.52
General epistemology (CFI)	3.77	0.60	3.86	0.70
Learning complexity (overall)	0.01	0.38	−0.02	0.55
Building knowledge connections	0.01	0.43	−0.01	0.81
Building flexible understanding	0.07	0.45	−0.07	0.52
Evaluating web information	0.08	0.44	−0.09	0.56
Basic strategies	0.04	0.50	−0.04	0.97
Advanced strategies	0.13	0.60	−0.13	0.49
Engaging in inquiry	−0.08	0.65	0.08	0.74
Setting and completing goals	0.01	0.57	−0.01	0.73

Note. CFI = Cognitive Flexibility Inventory.

Research Question 1 (General Epistemology and Learning Complexity)

Results (see Table 7) showed that general epistemology was positively associated with the overall learning complexity ($\beta = .47$, $p < .001$, *f-square* = 0.48). This result supports Hartley and Bendixen's (2001) assumption of the epistemology-learning association in web-based open-ended ill-structured learning environments and indicates that learners with certain views about knowledge and learning are more likely to experience deep and complex learning processes in ill-structured domains.

This study also showed that personal epistemology was positively associated with all five categories of learning strategies—*Building knowledge connection* ($\beta = .44$, $p < .001$, *f-square* = 0.36); *Building flexible understanding* ($\beta = .35$, $p < .01$, *f-square* = 0.17); *Evaluating web information* ($\beta = .23$, $p < .05$, *f-square* = 0.08); *Engaging in inquiry* ($\beta = .43$, $p < .01$, *f-square* = 0.28); and *Setting and completing goals* ($\beta = .34$, $p < .01$, *f-square* = 0.17). That is, individuals who believe that knowledge is interrelated, complex, tentative, contextual, and developed from reasoning are more likely to invest effort in integrating

Table 6. Zero-Order Correlation Coefficients for All Study Measures.

Measure	2	3	4	5	6	7	8	9	10	11	12	13
1. Prior knowledge	0.15	0.15	−0.08	0.09	0.18	0.04	0.21	0.18	0.19	−0.00	0.14	0.15
2. Verbal comprehension		0.02	0.09	0.13	0.31*	0.31*	0.21	0.38**	0.23	0.35*	0.05	0.31*
3. Time			0.02	0.12	0.51***	0.43**	0.36**	0.45**	0.45**	0.13	0.40**	0.36**
4. Effort				0.05	−0.04	−0.01	0.00	0.04	0.08	−0.05	−0.12	−0.03
5. CFI					0.55***	0.51***	0.41**	0.33*	0.14	0.38**	0.46**	0.41**
6. Learning complexity (overall)						0.85***	0.78***	0.70***	0.63***	0.55***	0.81***	0.77***
7. Building knowledge connections							0.60***	0.53***	0.38**	0.40**	0.59***	0.58***
8. Building flexible understanding								0.52***	0.30*	0.49***	0.62***	0.41**
9. Evaluating web information									0.83***	0.56***	0.36**	0.43**
10. Basic strategies										0.01	0.25	0.27
11. Advanced strategies											0.28*	0.11
12. Engaging in inquiry												0.52***
13. Setting and completing goals												–

Note. CFI = Cognitive Flexibility Inventory.
*$p < .05$.
**$p < .01$.
***$p < .001$.

Table 7. Hierarchical Multiple Regression Results Predicting Overall Learning Complexity.

Model Parameters	Control β (*SE*)	Beliefs β (*SE*)	Activation β (*SE*)	Interaction β (*SE*)
Step 1—Control variables $F(4, 48) = 6.57$, $p < .001$				
Prior knowledge	0.05 (0.02)	0.03 (0.02)	0.03 (0.02)	0.03 (0.02)
Verbal comprehension	0.30* (0.01)	0.24* (0.01)	0.24* (0.01)	0.24* (0.01)
Time	0.49*** (0.002)	0.44*** (0.002)	0.44*** (0.002)	0.44*** (0.002)
Effort	−0.07 (0.09)	−0.09 (0.08)	−0.08 (0.08)	−0.09 (0.08)
Step 2—General epistemic beliefs $F(1, 47) = 22.67$, $p < .001$				
CFI		0.47*** (0.07)	0.47*** (0.07)	0.49*** (0.10)
Step 3—Activation (group) $F(1, 46) = 0.06$, $p = .81$				
Activation			0.02 (0.09)	0.02 (0.10)
Step 4—Interaction $F(1, 45) = 0.05$, $p = .82$				
CFI × Activation				−0.03 (0.10)
ΔR^2		.21***	.00	.00
Total R^2	.35***	.56***	.57***	.57***

Note. Standard errors (*SE*) follow parameter estimates in parentheses. CFI = Cognitive Flexibility Inventory.
*$p < .05$.
**$p < .01$.
***$p < .001$.

knowledge, building flexible knowledge representations, evaluating information credibility, engaging in inquiry, and being learning-oriented during their ill-structured Internet search activities.

Among these five categories, the positive relationship between epistemic beliefs and knowledge integration has been found in other studies (e.g., Barzilai & Zohar, 2012; Bråten & Strømsø, 2006b, 2009) conducted with multiple texts and the open-ended web among six graders and university students. Because these studies were set up differently (e.g., different topics, different instruments to measure personal epistemology, and so on), such congruence may indicate the strong relationship between epistemic beliefs and knowledge integration.

In this study, the *Evaluating web information* category was further investigated through two lenses: (a) participants adopted basic strategies for web information evaluation—such as evaluating URLs and the identity of authors (i.e., the *Evaluated source* code in Table 1) and assessing the recentness of websites (i.e., the *Evaluated recentness* code in Table 1) and (b) participants adopted advanced strategies to assess the content of web information—such as writing levels, sufficiency of evidence, logical soundness (i.e., the *Evaluated reasoning, Evaluated citations, Evaluated quality of writing*, and *Evaluated via triangulation* codes) and taking goals and biases into consideration (i.e., the *Evaluation was contextual, Evaluated universal bias*, and *Reminded themselves about bias codes*). Statistical analysis in this study showed that participants' general epistemic beliefs were connected positively to their use of the advanced strategies ($\beta = .37$, $p < .01$, *f-square* = 0.23), not to the use of the basic strategies. That is, all participants knew to adopt basic strategies to evaluate the quality of web information. Yet, learners with more sophisticated epistemic beliefs seemed to be able to focus on higher levels of strategies to evaluate the content of web information they encountered. This finding, thus, supports Spiro et al.'s (1996) assumption that learners with expansive and flexible epistemic worldviews may better suit complex and advanced knowledge acquisition in ill-structured domains.

Three methods were used to enhance the reliability of measuring participants' learning processes: (a) all think-aloud protocols were coded twice by the same researcher, (b) intercoder comparison was conducted, and (c) method triangulation (between interview protocols and think-aloud protocols) was conducted. These efforts enhance our confidence in reporting the results.

Research Question 2 (Epistemic Activation and Learning Complexity)

Epistemic activation did not show its influence on the overall learning complexity or its five categories (i.e., *Building knowledge connection, Building flexible understanding, Evaluating web information, Engaging in inquiry*, and *Setting and completing goals*). Epistemic activation, however, increased the likelihood that participants adopted advanced strategies to evaluate the content of web information ($\beta = .28$, $p < .05$, *f-square* $= 0.14$, $d = 0.47$). The participants responding to the epistemic prompts might have gained an opportunity, prior to learning, to contemplate higher level strategies to evaluate the web information credibility. This finding leads to a more interesting question—Whether all the participants in the activation group benefited from this epistemic activation opportunity? This question will be addressed soon.

In general, the epistemic activation enacted in this study was not sufficiently effective to promote participants' complex and ill-structured knowledge exploration. Perhaps, it is because epistemic prompts were provided before learning, instead of during learning. Participants, even though contemplated prompts carefully, might not be able to keep their responses in mind when they were exploring the web. A few participants mentioned this situation during their interviews, admitting that once they started learning, they forgot to think about the prompts. On the other hand, some learning strategies may be more sensitive and responsive to the use of epistemic prompts prior to learning. The result supported this view by demonstrating the effectiveness of epistemic activation on the adoption of advanced strategies to evaluate web information. A close look at the data also showed that significantly more participants in the activation group (23 out of 27) checked out alternative views during their learning processes, $\chi^2(1) = 4.93$, $p = .035$. In the nonactivation group, only 15 (out of 26) participants did so.

Research Question 3 (General Epistemology, Epistemic Activation, and Learning Complexity)

There was no significant interaction effect (CFI × Group) on the overall learning complexity, or the *Building flexible understanding, Evaluating web information, Engaging in inquiry*, or *Setting and completing goals* dimensions. Yet, a positive correlation between the interaction term (CFI × Group) and adopting advanced strategies to evaluate web information ($\beta = .29$, $p < .05$, *f-square* $= 0.09$) existed. That is, compared with the participants in the nonactivation group, the participants in the activation group demonstrated a stronger correlation between their general epistemic beliefs and the likelihood to adopt advanced strategies to evaluate web information (see Figure 1). This result is consistent with Kitchener's (1983) assumption that epistemic activation before learning may enhance the epistemology-learning association. Conceptually, it is reasonable to assume that complex learners who believe knowledge is derived from reasoning rather than authorities are more likely to evaluate web information based on the soundness of reasoning, authors' biases, the quality of evidence, and so on. The epistemic activation designed in this study could have raised complex learners' attention to reasoning for quality learning, whereas the less complex learners, even though primed, might not perceive the role of reasoning, and thus, did

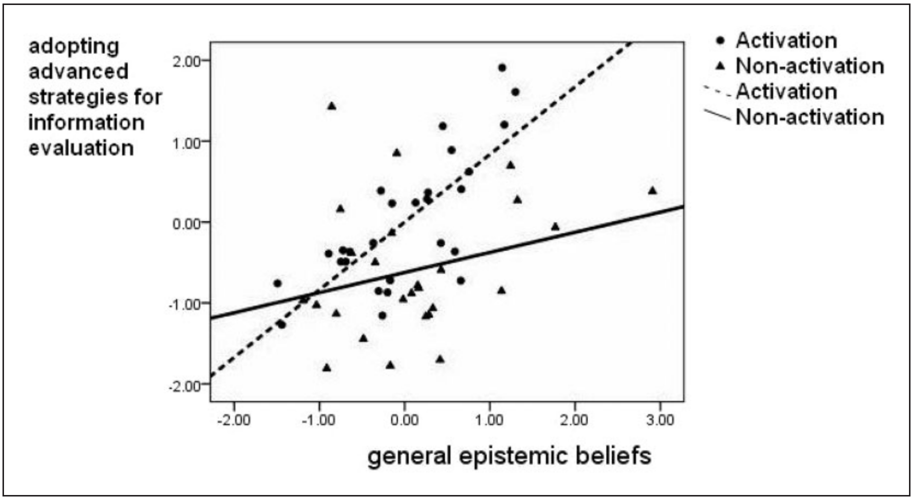

Figure 1. Partial regression plot (with regression lines) depicting the two-way interaction between general epistemic beliefs and epistemic activation on participants' adoption of advanced strategies to evaluate web information.

not take advantage of the epistemic activation to think about the advanced information evaluation strategies. Therefore, in this very specific case, prompts cannot be beneficial to all learners, but only to the most complex.

Results also showed a negative correlation between the interaction term (CFI $\times$ Group) and *Building knowledge connections* ($\beta = -.30$, $p < .05$, *f-square* $= 0.10$). Compared with the participants whose task-oriented epistemic beliefs were not activated before the task, those in the activation group had a weaker correlation between their general epistemic beliefs and their efforts for building knowledge connections in the learning processes (see Figure 2). Obviously, this interesting result is inconsistent with Kitchener's (1983) assumption that epistemic activation could strengthen the epistemology-learning relationship. To some extent, the finding indicates that the prompts composed in this study were not effective to activate participants' *simplicity of knowledge* (i.e., the epistemic dimension about the connectivity of knowledge). Yet, prior studies (Hofer, 2004; Mason et al., 2010) have shown that learners have trouble spontaneously activating the *simplicity of knowledge* dimension during their Internet search activity. We designed the prompts to activate rather than to change participants' task-oriented epistemic beliefs; and thus, this dilemma raises an important research question to be addressed in the future: How to activate the *simplicity of knowledge* dimension effectively?

Finally, the epistemic activation in this study may have an effect on participants' evaluation of task complexity. When piloting the prompts, some participants reported that contemplating epistemic prompts enhanced their

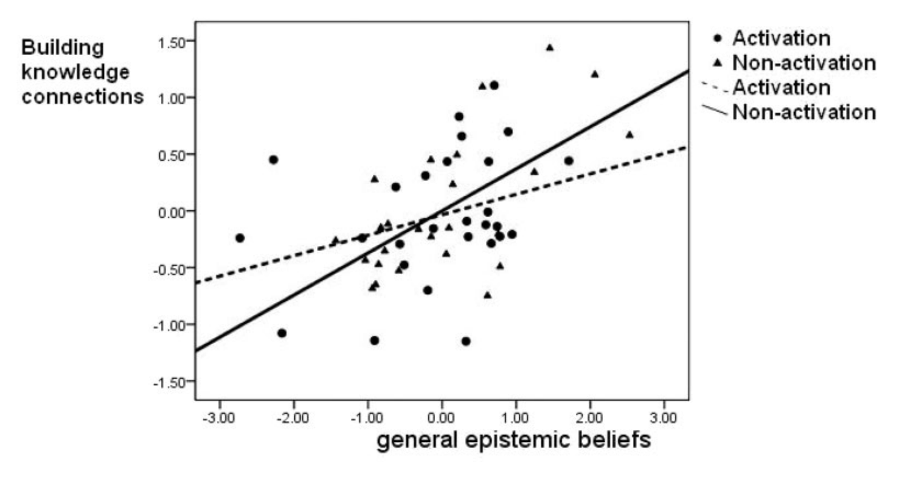

Figure 2. Partial regression plot (with regression lines) depicting the two-way interaction between general epistemic beliefs and epistemic activation on building knowledge connections.

awareness of the complexity and subjectivity nature of the searching task. This seemed to be supported by our data—for the participants who spent the same amount of time exploring the given task, those in the activation group (adjusted $M = 5.90$, $SE = 0.11$) felt that their effort investment in exploring the task was less adequate than the ones in the nonactivation group (adjusted $M = 6.22$, $SE = 0.11$; $F(1, 50) = 4.08$, $p < .05$, $\eta^2 = .08$). Perhaps this was caused by the epistemic prompts that raised participants' awareness of the complexity of the task; and thus, at the end of learning, those who received the prompts were less likely to feel learning sufficiency.

Conclusion

Exploring ill-structured tasks using the Internet requires complex knowledge exploration. This study demonstrates that individual differences in their epistemic beliefs may favor some types of learners for complex and deep learning in open-ended and ill-structured domains. This study also examined the role of a pedagogical intervention that can be easily adapted in classroom settings as well as for online instructions and found out that learners with varying levels of epistemic beliefs may benefit differently from epistemic prompts, and how well they benefit from the prompts may also rely on specific learning strategies (e.g., advance strategies for web information evaluation, attention to alternative views, learner perception of task complexity, etc.).

Limitations

When reflecting on the design of this study retrospectively, perhaps general epistemic beliefs should have been measured before the interview because the interview questions may prime participants to be more epistemically complex. In addition, this study makes an initial attempt to examine the role of epistemic activation, and we knew too little about how to write an effective epistemic prompt. While the role of epistemic activation may vary based on specific learning strategies, it is also unclear how each prompt could have affected participants' knowledge exploration processes, and how prompts should be written to maximize their benefit. Clearly, it will be very informative if future studies can provide more details on the specific relationship between epistemic prompts and learning strategies. It is also important to examine the issue on how to activate the *simplicity of knowledge* dimension due to the fact that this epistemic dimension was not easily activated spontaneously in prior studies (Hofer, 2004; Mason et al., 2010).

Implications

Despite the limitations, the results inform teachers and educators to attend to learner characteristics for deep learning in ill-structured and web-based learning environments. Teaching should focus not only on increasing students' content knowledge but also on cultivating students' complex beliefs about knowledge and knowing. Some recent studies were conducted to seek and examine pedagogical interventions to improve learners' epistemic beliefs (Ferguson, Bråten, Strømsø, & Anmarkrud, 2013; Kienhues, Stadtler, & Bromme, 2011; Mason, Junyent, & Tornatora, 2014; Muis, 2007), and more studies will be beneficial.

This study also reveals that using prompts to activate learners' task-oriented epistemic beliefs before learning may enhance their feeling of task complexity, trigger the action of exploring alternative views, and increase the likelihood of using advanced strategies to evaluate web information. Thus, before sending students to explore a task in front of computers, it may be wise for instructors to prepare some questions or initiate a classroom discussion, asking students to reflect on the nature of knowledge and knowing. Or if it is an online course, the instructor can post some questions for epistemic reflections and encourage students to think about it individually or to discuss in groups. The effectiveness of these suggested instructional practices, however, should be further tested and validated in school settings.

Appendix A. Epistemic Activation Prompts

Before you begin, we would like you to contemplate the following five scenarios. Please answer the questions embedded in each scenario with as much detail as possible. The purpose of this exercise is not to test how well you can answer the questions, but to help prepare your mind for the upcoming task. If, while answering these questions, you have any thoughts on how to best carry out your online research, feel free to jot them down to assist you later.

1. When you study the effect of genetic engineering on human health, you can find and read
   1) summaries posted by different people or organizations (e.g., conclusions from the World Health Organization website, effects of GE products presented online as bullet points, etc.); or
   2) individual cases posted by different people (e.g., consumers describing their health issues after eating GE foods, physicians' and nutritionists' opinions on GE products, farmers talking about their GE crops, specific studies testing the safety of a certain type of GE food, interviews to policy makers, representatives of biotechnology companies, ecologists' observations of agricultural system in which GE crops grow, etc.).

   By which of these two approaches do you think you can understand the issue better and is more helpful to form and justify your own view on whether GE crops are safe to eat? Why?
2. Do you think it is possible that two trustworthy websites may show opposing information on a certain topic (e.g., opposing results found in rat feeding tests assessing the impact of a certain type of GE potato on rats' immune system)? Why or why not? What are some possible explanations you can think of for the contradiction?
3. As you build your own knowledge about the given topic, how certain are you that what you read is true, reasonable, or believable? What factors do you think may affect the veracity of web information? What evidence, facts, or empirical data will you decide is acceptable justification for particular views related to this topic?
4. Suppose you find several websites providing evidence to support the view that GE foods are safe to eat, but several other websites provides evidence that GE foods are unsafe to eat. Which one of the following situations is most likely?
   1) One view is correct, and the other view is incorrect.
   2) Both views can be equally correct or incorrect.
   3) One view is more correct or reasonable than the other, but both can be correct or incorrect to some extent.

   Why? What are some possible explanations you can think of for the contradiction?

   How will you reconcile inconsistent information when judging whether GE foods are safe to eat?
5. Does the issue—whether GE foods are safe to eat—have a clear and correct answer? Why or why not? How would you address this issue, and how do you know if you have learned this issue thoroughly and sufficiently?

Appendix B. The Revised CFI Measuring General Epistemic Beliefs

Part I.

- Each of the following items contains two opposing statements about learning.
- Please select the degree to which statement matches how you think.
- Only one option on each item (or line) can be selected.
- There is no right or wrong answer, and we just want to know how you think.

Example

For the following item:

Item1	I am an introverted person.	○	○	○	○	○	○	I am an extroverted person

Statement A	Strongly agree with A	Mostly agree with A	Somewhat agree with A	Somewhat agree with B	Mostly agree with B	Strongly agree with B	Statement B

Thus, if you think that you are more likely to be an introverted person, you may select:

Item 1	I am an introverted person.	○	●	○	○	○	○	I am an extroverted person

---

[Part I starts below…]

1	I have learned some topic best when I can account for various phenomena using some single, more abstract, explanatory system, framework or perspective.	○	○	○	○	○	○	*I have learned some topic best when I can examine its various phenomena through different explanatory systems, frameworks or perspectives.*
2	Complex topics should be best broken down into parts and studied separately. In most areas of study, the whole topic is usually equal to the sum of its parts.	○	○	○	○	○	○	*Breaking down complex topics into separate parts is often misleading because components tend to interact and affect each other. In most areas of study, the whole is usually not the same as the sum of the parts.*
3	Different aspects or sub-topics of knowledge should be compartmentalized in the mind so that I can see how one aspect can neatly build off the rest.	○	○	○	○	○	○	*Different aspects or sub-topics of knowledge should be highly interrelated in the mind along varying dimensions so that I can see their different roles from different perspectives.*

4	*When phenomena appear inconsistent, it is probably because a single system or lens for explanation can not be found. Multiple explanatory systems should be used so that they could be explained thoroughly.*	○	○	○	○	○	○	When phenomena appear inconsistent, it is probably because a system for explaining them has not yet been found. But, it is likely that such a system exists.
5	*I enjoy encountering difficult, conflicting, and disorderly concepts and find them challenging.*	○	○	○	○	○	○	I prefer simplicity, consistency, and orderliness. Whenever possible, I prefer not to encounter complex concepts in school (although I deal with complexity when I have to)
6	I feel intolerant of ambiguity or inconsistency, because it indicates a limit to what is known. Things should have a clear answer if we know enough about them.	○	○	○	○	○	○	*I do not find ambiguity or inconsistency too troubling. It's all right if things don't always have a clear answer or cannot be explained uniformly. Yet it is essential that I should know underlying factors accounting for the ambiguity and inconsistency.*
7	*Ideas need to 'come to life'. Concepts should be personally experienced in a vital manner.*	○	○	○	○	○	○	The notion that ideas should 'come to life' makes no sense. Concepts are merely abstractions.
8	When previously learned information has to be applied, I usually tend to recall some general rule and then try it out in the new situation, or I usually recall the general process	○	○	○	○	○	○	*When previously learned information has to be applied, I usually recall specific contexts in which I use some general rule to solve similar problems. Then I try to align these*
	of solving other cases for what I should do in the new situation.							*contexts with the context of the new case. I usually do NOT directly try out some general rule or follow some general process when I deal with new cases.*
9	*Learning is essentially a process in which I personally construct understandings and acquire the ability to apply my knowledge in new ways to various kinds of new situations.*	○	○	○	○	○	○	Learning is essentially a process that I receive information, record it appropriately in my memory, and retrieve it accurately for later use.

10	Learning works best when I am told explicitly what I am supposed to learn and how I should learn.	○	○	○	○	○	○	*Learning works best when I am left with a lot of flexibility regarding what should be learned and how I should learn.*
11	*Learning works best for me when it is self-directed.*	○	○	○	○	○	○	Learning works best for me under the guidance of experts (e.g., teachers).
12	I am very concerned with how others evaluate me. Doing well on exams is my most important learning goal.	○	○	○	○	○	○	*I set my own personal standards; self-evaluation matters most to me. Exams are important, but they are not the ultimate goal of my learning.*
13	All scientific and theory-based issues should have a single certain absolute answer applicable to all situations if they are well studied.	○	○	○	○	○	○	*All issues could NOT have any certain absolute answer applicable to all situations, even if they are well studied and are scientific and theory-based.*
14	I am highly motivated by external factors (e.g., what other people expect of me).	○	○	○	○	○	○	*I am highly motivated by internal factors (e.g., what I intrinsically want to do and think is best).*

Appendix C. Prior Content Knowledge Test

1. A large amount of GE/modified food safety research has been conducted on human subjects and has shown that GE foods can be risky to human health.
   a. True b. False c. I don't know
2. Foods made from GE/modified crops are required to pass human testing conducted by the Food and Drug Administration (FDA).
   a. True b. False c. I don't know
3. Most foods derived from GE/modified crops contain the same number of genes as food produced from their conventional (non-GE/modified) crops.
   a. True b. False c. I don't know
4. If we live in the United States, it is almost certain that we have eaten foods that are genetically modified.
   a. True b. False c. I don't know
5. Labeling food that is genetically modified is NOT required in the United States.
   a. True b. False c. I don't know
6. Individual GE/modified foods and their safety investigations should be assessed on a case-by-case basis because different genetically modified organisms include different genes inserted in different ways.
   a. True b. False c. I don't know

7. When genetic modification was first introduced on the market, its major goal was to produce crops with more nutritional value.
   a. True b. False c. I don't know
8. GE/modified plants are now being developed for the production of recombinant medicines and industrial products, such as vaccines, plastics, and biofuels.
   a. True b. False c. I don't know
9. GE/modified plants can be used to produce drugs to treat human disease.
   a. True b. False c. I don't know
10. GE/modified plants can NOT contaminate the ecosystem.
   a. True b. False c. I don't know
11. A GE/modified plant can contain a gene from an unrelated plant or from a completely different species.
   a. True b. False c. I don't know
12. Monsanto is a biotechnology company providing most of the GE seeds.
   a. True b. False c. I don't know
13. Biotechnology companies are required to conduct safety test of new GE crops before marketing them.
   a. True b. False c. I don't know
14. U.S. Department of Agriculture (USDA), Environmental Protection Agency (EPA), and Food and Drug Administration (FDA) are currently three agencies regulating the safety of genetic engineered crops in the United States.
   a. True b. False c. I don't know
15. What else do you know about GE crops and its safety issues? Please specify below:

Appendix D. Effort Survey

Please read each statement below and indicate the number that best applies to you.

PLEASE BE HONEST! There is no right or wrong answer!

1. Do you think you have sufficiently invested effort in the task?
   1--------2---------3---------4-------5-------6--------7
   Not sufficient at all Completely sufficient

2. How would you rate the completeness of the information you researched about the topic online?
   1-------2---------3---------4----------5----------6------------7
   I did the minimal I searched extensively

search to finish the task quickly | until I did not find more worthwhile information

3. Do you think you have sufficiently explored the topic to the fullest degree necessary?
   1----------2----------3---------4--------5---------6---------7
   Not at all Yes, completely

Appendix E. Retrospective Interview Questions

1. Did you check the existence of alternative views, disconfirming evidence, or different ways to interpret a certain issue? If so, please provide some examples.
2. Did you do anything to evaluate the trustworthiness of the web information you read? If so, please provide some examples.
3. To what extend did you pay attention to the things such as how certain views or conclusions on the web were formed, how well these views or conclusions could be applied to other situations? Provide some examples.
4. To what extend did you try to find or read personal opinions or individuals' experiences or stories? Provide some examples please.
5. While you were researching the given topic, to what extent did you try to connect, compare, synthesize, or integrate web information you read on different sites? Provide some examples.
6. How did you approach this learning task to form your own view on whether GE foods are safe to eat?

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