A Theoretical Framework for Online Inquiry-Based Learning

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Abstract: Current research on inquiry-based learning has biases by extensively focusing on the face-to-face contexts in the domains of mathematics and sciences and ignoring online contexts in other disciplines. This may be due to the following reasons. First, we have not developed a comprehensive view of current research on inquiry-based learning across different subject domains. Second, we have not systematically explored how the current relevant research on face-to-face learning contexts can be implemented in the online contexts. Therefore, the goal of this paper is to establish a theoretical framework of inquiry-based learning across different areas and analyze how this framework can be implemented in the online context. Further research directions of online inquiry-based learning have also been discussed in this paper.

Recently, inquiry-based learning has gained renewed emphasis and gradually become the central theme in educational research and practice (Edelson, 2001; Short, 1996; Wells, 1999), including in online learning contexts. Numerous inquiry-based instructional models, such as Authoring Cycle (Short, Harste, & Burke, 1996) and Inquiry Cycle (White & Frederiksen, 1998) have been developed to support different learning activities. Obviously, it is critical to understand learning that occurs under different inquiry-based instructional models. Current literature addressing inquiry-based learning has biases. First, it focuses intensively on students from elementary to high school in mathematics and science areas (Hancock, Kaput, & Goldsmith, 1992; Linn & Slotta, 2000). Second, there is a paucity of research about inquiry-based learning in an online context. The inquiry-based learning approach should be applied to a variety of fields and contexts, but literature seems to ignore them. Therefore, there is an extensive need to extend the scope of current research on inquiry-based learning by forming a comprehensive understanding of current research and theory on inquiry-based learning, and to analyze how the current relevant research and theory can inform the implementation of inquiry-based learning online, which is the goal of this theoretical framework paper.

The Definition of Inquiry-based Learning

Inquiry-based learning refers to a learning process. It usually begins with posing a problem or question, followed by generating and pursuing strategies for investigating, collaborating, reflecting, and justifying the solutions of the problem or answers to the question, and communicating the conclusions. The learning outcomes are higher-order thinking skills and development of a deep understanding of disciplinary knowledge (Bransford, Brown, & Cocking, 1999). From a learning perspective, it is students who conduct this inquiry. From an instructional perspective, inquiry is a way to organize activities, usually through different inquiry models (Sandoval, 2005). In this paper, the meaning of inquiry-based learning refers to a learning process regulated by various inquiry models. Specifically, I examine what the crucial components are that make up an inquiry-based learning process proposed by various inquiry models.
Inquiry Models

Learning Cycle - Project-Based Learning in Scientific Inquiry

The Learning Cycle was proposed in the later 1950s and the early 1960s, and was advocated to echo the claims of that time that students should engage in activities very similar to those of professional scientists (Edelson, 2001). Scientists’ inquiry processes usually consist of three phases: 1) exploration: gathering evidence, 2) invention: naming concepts and introducing relationships; and 3) discovery: using concepts, etc., to investigate other phenomena (Edelson, 2001). The Learning Cycle was developed to represent class activities parallel to those of scientists (Edelson, 2001). Basically, in the exploration phase of the Learning Cycle, students engage in hands-on laboratory work or field trips. In the invention phase, students discuss concepts introduced by the teacher or their experience; in some Learning Cycles, this term invention is replaced by introduction. In the discovery phase, students try to apply what they learn. Some Learning Cycles replace discover with application to reflect more accurately the practice in the classroom (Lawson, 1995; Llewellyn, 2002). There are some variations of the Learning Cycle developed to fit different instructional needs. The project-based learning model of 1) asking a question, 2) designing investigations and planning procedures, 3) constructing an apparatus and carrying out investigations, 4) analyzing data and drawing conclusions, and 5) collaborating and presenting findings is an example (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998).

The common feature of the Learning Cycle group of models is that different steps in these Learning Cycle models are named according to the teachers’ and students’ activities, which are assumed to be very similar to that of scientists (Edelson, 2001). However, the similarity of the activities does not necessarily reflect the cognitive differences between students and scientists which make their inquiry activities qualitatively different, as illustrated by Chine and Malhotra (2002). This group of models usually makes no distinction between doing good work in activities and making progress in learning, an approach which has been criticized by Scardamalia & Bereiter (1991).

El’konin-Davydov’s Learning Cycle – Mathematics, Linguistics, Art, Literature and Science

The weakness in activity-emphasis inquiry models calls for more sophisticated models that could facilitate students’ “good” learning through reflecting scientists’ cognitive activities (Rudolph, 2005). One such model proposed by Zuckerman, Chudinova, & Khavkin (1998) is under the El’konion- Davydov educational system. The model suggests that students are introduced to new knowledge of a subject by discovering for themselves the most general features of the particular subject, which later are represented in a model. Then, students challenge this model with new empirical data, which lead them to expand and reconstruct the initial model and look at the phenomenon under study through the lens of the model. Then the essential features are studied and verbalized in scientific terms as the initial concepts. Further study takes the form of enriching the initial concepts every time a new fact arises, and students come up against the discrepancies between the knowledge in the model and a new fact (Zuckerman, Chudinova, & Khavkin, 1998). More specifically, six steps are included in the learning cycle: 1) evoking children’s curiosity; 2) experimental verifying of hypotheses through asking questions, making predictions and hands-on verification; 3) modeling the preliminary concepts; 4) cooperating with peers, which helps students assimilate new concepts, terms, and methods; 5) enriching the initial model through explication of contradictions between the phenomena depicted; and 6) stating new problems (Zuckerman, Chudinova, & Khavkin, 1998).

Another example is the Inquiry Cycle model for science education, which emphasizes how students can develop their scientific concepts and models through the sequence of the inquiry process. It consists of five steps: 1) asking a well-formed, investigable research question, 2) generating a set of competing hypotheses to predict relevant phenomena, 3) carrying out experiments to test hypotheses, 4) constructing scientific models based on their findings, and 5) applying their models to various situations (White & Frederiksen, 1998).

The common features of the above models are their emphasis on 1) knowledge construction, a particular form of knowledge – models, and 2) knowledge validation and refinement, in which students are required to check the coherence between the empirical data and models grounded on their data. Thus, this group of inquiry models reflects the cognitive processes of scientists’ constructing and justifying ideas rather than their observable activity to produce artifacts (Rudolph, 2005). From this perspective, the focus of this group of models is on the epistemological aspect of learning in which students are guided to engage in a process of knowledge production, validation and refinement very similar to that of scientists (Sandoval, 2005).

Which is better, activity-emphasis or epistemology-emphasis, in regard to facilitating learning? Two empirical studies can answer this question. Krajcik, Blumenfeld, Marx, Bass and Fredricks (1998) report on
students’ learning experiences under the project-based model. They find that many middle school students in their study “did not develop a logical argument to support their claims; they tended to present data and state conclusions without explicitly linking the two” (1998, p.347). Therefore, students lack the knowledge validation skill in the project-based model. But this skill is mastered by students in the Inquiry Cycle model. White & Frederiksen (1998) reported that middle school students in the Inquiry Cycle perform well by reasoning “how experimental observations support or refute a model”(White & Frederiksen, 1998, p.67). Close examination of these two models shows that the Inquiry Cycle model explicitly incorporates knowledge production, validation and refinement in the model (Steps 4 and 5), while project-based learning vaguely uses the terms “analyze data and draw conclusions.” In the best situation, it expresses them in an implicit way. In the worst situation, it loses the crucial components in its model. This lack of those components is correctly reflected in the students’ learning outcomes, as reported by their research study.

Authoring Cycle for Literacy

Realistically, an inquiry model seldom stays at extreme ends of the inquiry continuum, with one end being activity-emphasis and with epistemology-emphasis on the other end. Most of them are combinations of the two. For example, Short (1996) proposes Authoring Cycle for improving learners’ literacy. There are seven steps in the Authoring Cycle: 1) building from the known, 2) taking time to find questions for inquiry, 3) gaining new perspectives through collaboration and investigation, 4) attending to difference: revise what we know for discrepancy between observation and theory, 5) sharing what was learned through transformation and presentation, 6) gaining new inquiries based on reflection, and 7) taking thoughtful new action. This model is closer to activity-emphasis with some epistemology-emphasis elements at step four.

Components in an Inquiry-Based Learning Process

Based on the above analysis, the following components seem to be indispensable in an inquiry-based learning process suggested by the above models. These components are asking questions, gaining new understanding, and making presentations (Tab. 1).

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Table 1: Components suggested by inquiry models.

Asking Questions
All inquiry models suggest that asking questions is the first or very early step in the inquiry-based learning process (Short, 1996; White & Frederiksen, 1998). These models also suggest students’ own interests and goals should drive the inquiry process, instead of answering a teacher-posed question of no interest to the students (Short, 1996). This does not mean that only student-posed questions can initiate an inquiry; questions posed by teachers or other source can also initiate an inquiry. What is at issue is the students’ attitude toward the question or topic, rather than from where it comes (Wells, 2000).

### Gaining New Understanding

This component suggests that through several sub-steps, either through the collection of data or recursively building and refining models, solutions posed in the first step have been found, or questions have been answered. Inquirers have gained new understanding about the domain in which they conducted their inquiry. Of course, it is possible that students gain new understanding at other steps in the inquiry-based process. But obviously this part is the most important part in which students gain new understanding through inquiry. This is also where different models are distinguished from each other.

There are at least three sub-steps that should be included in this step suggested by some, though not all, of the discussed models. One is getting or exploring data through experimenting, observing, interviewing or collecting Internet information (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998). The second is to construct various forms of knowledge based on the reasoning and interpreting of the collected data. The forms of knowledge could be concepts, laws, theories, models, hypotheses, or points of view (White & Frederiksen, 1998). The third sub-step is knowledge validation and refinement; the task of this step is to check whether the constructed knowledge is grounded in the data. Many skills can be used at this step, including explaining a proposition, argument or refuting a claim, etc. The result is refined knowledge structures and improved understanding of knowledge (White & Frederiksen, 1998). In the above discussion, we know that epistemology-emphasis inquiry models are better than activity-emphasis ones in regard to facilitating students’ learning because they focus on knowledge production, validation and refinement. If knowledge construction, validation and refinement is at the heart of inquiry (Sandoval, 2005), then this second step is where the heart of inquiry lies.

![Figure 1: A Framework for Inquiry-based Learning Process](image-url)

### Presentation

Presentation is the final stage to an inquiry-based learning process. At the same time, some models suggest that presentation is the starting point for a new inquiry. Presentation is also a very important part in which students demonstrate what they have learned in the prior inquiry steps (Short, Harste, & Burke, 1996). Usually, presentation can create discourse among students and various audiences, such as parents, teachers, and other public audiences. At this stage, students receive feedback from other people. Also, students can identify weaknesses of their inquiry-

Up to now, we have discussed the three key components and three sub-components of the inquiry-based learning process. Although there is a natural or inherent ordering among these steps, the ordering does not have to be fixed; they can overlap each other or occur cyclically. Actually, they are mutually determined within a dynamic interrelationship among all the components (Fig 1).

**Implementing Inquiry-Based Learning Online**

Schlosser & Simonson (2002) define distance learning as “institution-based, formal education where the learning group is separated, and where interactive telecommunication systems are used to connect learners, resources, and instructors” (p.1). Here, online or Web-based learning refers to a form of distance learning where interactive telecommunications systems are mainly Internet-based technologies. In the above section, we have discussed current inquiry models in the literature, which suggest several components that should be included to frame a meaningful inquiry-based learning process. Because these components are synthesized from models that are designed for face-to-face learning settings, to implement them in an online context, we need to consider the following:

**Asking Questions**

Asking questions is the first step in the inquiry-based learning process (Short, 1996; White & Frederiksen, 1998). Usually, in the face-to-face context, the teacher has lots of strategies for students to ask well-formed questions; for example, teachers can set up peer interviews to help students to identify their interests and investigable questions (Tallman & Joyce, in press). However, in the online context, with the separation of teacher and students in the process of teaching and learning (Gunawardena & McIsaac, 2003), those strategies have to be transformed to suitability for online learning. To facilitate asking questions online, we can utilize the flexibility of the “any time and any place” online context, and give students opportunities to arrange their own learning environments and time to seek good questions through interaction with their friends, family members, colleagues, etc. (Petrides, 2002). In addition, teachers can also use online communication technologies, including WebCT discussion boards, to pose their students’ inquiry questions online, and to ask for feedback from class. In addition, as Zuckerman, Chudinova, & Khavkin (1998) point out, students need to learn to ask scientific, systematic questions instead of naïve questions. Teachers’ scaffolding through online communication is crucial to help students transcend from naïve to systematic questioning by asking better questions based on students’ initial naïve or incomplete questions (1998).

**Gaining New Understanding**

**Exploring Information or Gathering Data**

Online inquiry-based learning in this step might include interviewing people, carrying out experiments, etc., which are the same as in the face-to-face learning contexts. But it might also involve large amounts of exploration of online information. There are unlimited static and dynamic resources on the Web (Hill & Hannafin, 2001). The open-ended Web resources for online learning can afford students the opportunities to pursue various inquiry topics that interest them. However, compared to traditional well-defined learning contexts, students in these learning environments must possess significant discipline, knowledge and metacognitive, higher-order thinking skills. Students face more authentic, challenging, and open-ended problems in open-ended, ill-structured environments (Hill, 1999). Consequently, students often experience uncomfortable challenges learning in such contexts. These challenges include: 1) lack of divergent, critical thinking, self-regulating, and problem-solving skills (Hill & Hannafin, 2001); 2) disorientation in the hypermedia world because of fundamental differences between nonlinear, ill-defined open-ended environments and linear, well-defined traditional information systems (Hill, 1999); and 3) lack of sufficient metacognitive awareness and monitoring skills relevant to their learning needs (Greene & Land 2000). Scaffolding can help facilitate gathering information relevant to student topics. Scaffolding supports addressed in the literature include scaffolding tools, and conceptual, metacognitive, procedural and
strategic scaffolding (detail see Hill & Hannafin, 2001). These types of scaffolding can help inform the implementation of this step within inquiry-based learning.

**Construct Various Forms of Knowledge**

One feature distinguishing constructivist from traditional pedagogies is its emphasis on knowledge construction instead of knowledge copying (Piaget, 1970). When a knowledge-copy view is held, a “deductive process” (McCollum, 1978, p.73) is implemented, namely, authority-determined content, which is first passed to students. Rules, definitions, and generalizations are followed by data or examples to illustrate their validity. When a knowledge construction view is held, an “inductive process” is implemented:

- Learning is basically a procedure of confronting a specific event, problem, or issue; acquiring and describing a body of information related to the event, problem, or issue; analyzing causal relationships; and stating explanations that are logically supported by the data (McCollum, 1978, p. 73)

In this knowledge construction process, a wide range of forms of knowledge is generated. Sandoval proposes the importance of student understanding of the forms of knowledge desired as productions, which includes but is not limited to, laws, theories, models, explanations, and rhetorical forms (Sandoval, 2005).

To facilitate such knowledge construction online, we can consider the following approaches. First, we can utilize technology affordance in the online context to facilitate knowledge construction. There are lots of technologies which can support representations of different forms of knowledge. Windschitl (2000) introduces three types of tools, visualization tools, simulations and microworlds to develop inquiry-based learning. Those tools can be used to help construct different forms of knowledge generated by online learners. Second, we can encourage online discourse, because knowledge construction is socially situated and can be supported in a community (Lim, 2004; Topper, 2005). One strategy to encourage online discourse in knowledge construction is to provide discourse interventions to underscore the knowledge construction aspects of learning, such as asking students to make explanations or argumentations for particular concepts or models or their own points of view. Vries, Lund, & Baker (2002) call this type of discourse invention epistemic dialogue.

**Knowledge Validation and Refinement**

Knowledge validation relates to issues of what counts as scientific knowledge (Sandoval & Morrison, 2003). It has been addressed by several scholars. Schwab (1978) points out that a discipline consists of substantive and syntactic structures. Substantive structure determines how the concepts, principles, theories, and laws are organized to incorporate facts. Syntactic structures are ways to justify truth or falsehood, validity or invalidity, of a claim within a discipline. Thus, syntactic structures are methods to validate knowledge in a discipline. Zuckerman, Chudinova, & Khavkin (1998) also propose that one difference between scientific concepts and everyday notions is that the former have to be checked and rechecked.

Refining knowledge refers to reconstruction or expansion of current knowledge to account for new situations or data. This component has been illustrated in all the inquiry models except the project-based model. The meaning of this knowledge refinement can be traced back to Piaget, who proposes the concepts of assimilation and accommodation (Piaget, 1985). Refinement of knowledge occurs when the knowledge generated in the prior steps cannot embrace reality under inquiry in a coherent whole (Short, 1996).

To implement knowledge validation and refinement in the online context, the following scaffolding can be provided. The first scaffolding is to create student awareness of the tentative nature of knowledge, namely, knowledge is always constructed and reconstructed (refinement) and is subject to being tested. Developing their epistemological belief can better inform students’ inquiry-based learning in various learning contexts, including online (McCollum, 1978; Sandoval, 2005). Second is to ask students to check their own claims or points of view generated in their inquiry-based learning processes, such as checking the coherence between data and claims, and encouraging the students to refine their knowledge and account for any discrepancy between a claim and its supporting evidence (Coleman, 1998; de Vries, Lund, & Baker, 2002). In short, through all possible instructional scaffolding, we can help students to validate the knowledge generated in their learning processes, reflect on the origin of that knowledge, and organize it into a coherent system.
Presentation

Presentation usually is the last step in some inquiry models discussed above. At this step, the knowledge gap is filled around the inquiry topic, meaning has been made to answer the posted inquiry questions, and solutions have been found to address the inquiry problems. Students are ready to present and discuss their findings. Research has found online communication through written text (email, discussion) often facilitates deep thinking and clear expression (Song, Singleton, Hill, & Koh, 2004). Therefore, in the online context, presentation can take various written forms instead of face-to-face presentation. Students can publish their inquiry findings on Web sites. Comments and feedback from peers or instructors can also add discourse and reflection (Rosebery, Warren, & Conant, 1992; Topper, 2005). In short, implementing presentation online through written forms and promoting discourse around the students’ presentations can foster reflection and critical thinking in students’ online inquiry-based learning processes.

Implications

The theoretical framework proposed in this paper is an effort to extend our understanding about important elements that constitute the inquiry-based learning process. These are continually and dynamically interplaying with each other in online environments. Emphasizing one or some, while ignoring others, will lead to failure in adapting to a warranted direction. Guided by the framework, the following areas need further research.

First, the framework is developed based on inquiry models that are situated in face-to-face contexts. Current literature seldom explores inquiry-based learning in online contexts. It is not clear how online students conduct their inquiry-based learning. A qualitative study will enhance our understanding of this particular research aspect. Several compelling questions can be raised: 1) How do students propose their inquiry questions? 2) How do students systematically explore the information and collect data for their inquiry-based learning? 3) How do students construct various forms of knowledge in their learning processes? 4) How do students validate their knowledge generated in the inquiry-based learning processes? and 5) What are the challenges they face in their learning processes?

In addition, as we discuss above, discourse can support students’ inquiry-based learning. This matches the constructivist view that learning is essentially a social-dialogical activity (Duffy & Cunningham, 1996; Wells, 2000). Although online discourse has been explored by some scholars (Molinari, 2004; Topper, 2005), online discourse has not been systematically explored in the inquiry-based learning process. A qualitative study employing discourse analysis can be employed to answer the following questions: 1) What are the roles discourse plays in students’ online inquiry-based learning processes? and 2) How does discourse contribute to knowledge construction, validation and refinement in the inquiry-based learning process?

Finally, we have not been able to locate any studies, which systematically investigates how students respond to different elements in an online inquiry-based learning environment. Some questions that can extend our understanding about how the learning environment can facilitate inquiry-based learning processes are: 1) What are the components that should be included in an online inquiry-based learning environment? 2) What are students’ perceptions of those learning elements? and 3) How does students’ inquiry-based learning improve under the components in an online learning environment?

References


