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Review

Phases of inquiry-based learning: Definitions and the inquiry cycle

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ABSTRACT

Inquiry-based learning is gaining popularity in science curricula, international research and development projects as well as teaching. One of the underlying reasons is that its success can be significantly improved due to the recent technical developments that allow the inquiry process to be supported by electronic learning environments. Inquiry-based learning is often organized into inquiry phases that together form an inquiry cycle. However, different variations on what is called the inquiry cycle can be found throughout the literature. The current article focuses on identifying and summarizing the core features of inquiry-based learning by means of a systematic literature review and develops a synthesized inquiry cycle that combines the strengths of existing inquiry-based learning frameworks. The review was conducted using the EBSCO host Library; a total of 32 articles describing inquiry phases or whole inquiry cycles were selected based on specific search criteria. An analysis of the articles resulted in the identification of five distinct general inquiry phases: Orientation, Conceptualization, Investigation, Conclusion, and Discussion. Some of these phases are divided into sub-phases. In particular, the Conceptualization phase is divided into two (alternative) sub-phases, Questioning and Hypothesis Generation; the Investigation phase is divided into three sub-phases, Exploration or Experimentation leading to Data Interpretation; and the Discussion phase is divided into two sub-phases, Reflection and Communication. No framework bringing together all of these phases and sub-phases was found in the literature. Thus, a synthesized framework was developed to describe an inquiry cycle in which all of these phases and sub-phases would be present. In this framework, inquiry-based learning begins with Orientation and flows through Conceptualization to Investigation, where several cycles are possible. Inquiry-based learning usually ends with the Conclusion phase. The Discussion phase (which includes Communication and Reflection) is potentially present at every point during inquiry-based learning and connects to all the other phases, because it can occur at any time during (discussion in-action) or after inquiry-based learning when looking back (discussion on-action).

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Contents

1. Introduction

Inquiry-based learning is an educational strategy in which students follow methods and practices similar to those of professional scientists in order to construct knowledge (Keselman, 2003). It can be defined as a process of discovering new causal relations, with the learner formulating hypotheses and testing them by conducting experiments and/or making observations (Pedaste, Mäeots, Leijen, & Sarapuu, 2012). Often it is viewed as an approach to solving problems and involves the application of several problem solving skills (Pedaste & Sarapuu, 2006). Inquiry-based learning emphasizes active participation and learner's responsibility for discovering knowledge that is new to the learner (de Jong & van Joolingen, 1998). In this process, students often carry out a self-directed, partly inductive and partly deductive learning process by doing experiments to investigate the relations for at least one set of dependent and independent variables (Wilhelm & Beishuizen, 2003). It should be added that in the context of this study we are focusing on learners: what is new knowledge to them is not, in most cases, new knowledge to the world, even if the approach can be flexibly used by scientists in making their discoveries of new knowledge. In addition, it should be noted that an investigation does not always involve empirical testing.

Several quantitative studies support the effectiveness of inquiry-based learning as an instructional approach. Alfieri, Brooks, Aldrich, and Tenenbaum (2011), for example, performed a meta-analysis comparing inquiry to other forms of instruction, such as direct instruction or unassisted discovery, and found that inquiry teaching resulted in better learning (mean effect size of $d = 0.30$). A meta-analysis by Furtak, Seidel, Iverson, and Briggs (2012) incorporated studies using a broad range of terms to describe inquiry-based learning (e.g., mastery learning, constructivist teaching); they reported an overall mean effect size of 0.50 in favor of the inquiry approach over traditional instruction. A positive trend supporting inquiry-based science instruction over traditional teaching methods was found in a research synthesis by Minner, Levy, and Century (2010). In addition, it has been demonstrated that web-based guided inquiry-based learning can improve different inquiry skills, such as identifying problems, formulating questions and hypotheses, planning and carrying out experiments, collecting and analyzing data, presenting the results, and drawing conclusions (Mäeots, Pedaste, & Sarapuu, 2008). Recent technological advancements increase the success of applying inquiry-based learning even more (de Jong, Sotiriou, & Gillet, 2014). Educational policy bodies worldwide regard inquiry-based learning as a vital component in building a scientifically literate community (European Commission, 2007; National Research Council, 2000). Therefore, it is valuable to examine inquiry-based learning further in more detail and identify its core elements. In this article we present such a search for the key elements of inquiry-based learning. In doing so, we have taken an approach where we have focused only on inquiry-based learning described under this term. Several related areas have been excluded, such as discovery learning, project-based learning, game-based learning, and problem-based learning, as including these concepts would make our study too broad and the outcomes might not be easily applicable in the practical context in developing inquiry activities by teachers or educational designers.

Inquiry-based learning aspires to engage students in an authentic scientific discovery process. From a pedagogical perspective, the complex scientific process is divided into smaller, logically connected units that guide students and draw attention to important features of scientific thinking. These individual units are called inquiry phases, and their set of connections forms an inquiry cycle. The educational literature describes a variety of inquiry phases and cycles. For example, the 5E learning cycle model (Bybee et al., 2006) lists five inquiry phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. An inquiry cycle proposed by White and Frederiksen (1998) also identifies five inquiry phases, but labels them as Question, Predict, Experiment, Model, and Apply. An apparent distinction between these examples is that the initial phases of the 5E cycle (Engagement and Exploration) suggest starting with an inductive (empirical/data-driven) approach, whereas the first two phases of the White and Frederiksen inquiry cycle (Question and Predict) suggest a deductive (theory/hypothesis-driven) approach. However, both induction and deduction can coexist in an inquiry cycle. In fact, Klahr and Dunbar (1988) characterized the scientific reasoning process as a dual search in two spaces, which they call experiment space and hypothesis space. How researchers choose to balance inductive and deductive approaches in an inquiry cycle can influence the selection and/or arrangement of inquiry phases.