Inquiry and Problem-Based Learning in Secondary Science Education: An Overview and Comparison

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INTRODUCTION AND BACKGROUND

As with any subject area, there is a wide variety of instructional strategies that can be implemented in the secondary science classroom. All of these strategies provide a method for conveying scientific knowledge and understanding, and serve as a guide for how the instructor should approach a given lesson or unit. The particular strategy a teacher chooses will, in large part, determine how successful a lesson is. While there are assuredly external factors that influence learning outside of instructional technique (i.e. classroom behavior, environmental factors, and the varied learning needs of the students), how the teacher presents the material will have an enormous impact on student learning. For this reason, it is imperative that educators choose instructional strategies that will help students become excited and engaged in the material. However, it should be noted here that an educator's choice on which instructional strategy he uses is influenced by a variety of factors. School, district, state, and national curriculum policy, current research, and personal philosophy should all come into play when a teacher decides how to teach a lesson.

In the past three decades, secondary science education has seen two major pushes for curricular reform which have inevitably affected which instructional strategies classroom teachers choose to implement. In 1985 the American Association for the Advancement of Science (AAAS) launched "Project 2061," a national science, math, and technology reform effort. The name of the project provided a concrete timeline, "…with Halley's Comet in view that same year, the project's originators considered all the scientific and technological changes that a child entering school in 1985 would witness before the return of the comet in 2061. They chose the name Project 2061 to suggest that meaningful reforms to education depend on a long-term vision of the knowledge and skills that today's students will need as adults in the 21st

century" (Nelson, 1999). The AAAS released two major publications, *Science for All Americans* (AAAS, 1990) and *Benchmarks for Science Literacy* (AAAS, 1993), which served to identify the essential knowledge and learning goals that secondary students should strive for in the sciences.

The second major push for reform came in 1996 with the National Research Council's release of *National Science Education Standards* (NRC, 1996). Similar to the two works from the AAAS, this publication emphasized the importance of achieving scientific literacy in the classroom by creating more engaging student-centered curricula. Both reforms also strongly encouraged a curricular focus on the importance of the nature of science, and in particular, science as an inquiry-based discipline. At the root of these movements was the belief that too much of science education was focused on presenting finalized theories and facts in a traditional lecture setting, as opposed to allowing students to experience the dynamic and progressive nature of science through more interactive activities and labs. Due to this belief, and the standards and reforms set out in these movements, many teachers are beginning to make a shift to new instructional strategies that focus heavily on the nature of science and the active engagement of students in classroom activities. This essay will focus on two of these instructional strategies, Inquiry-Based Learning (IBL) and Problem-Based Learning (PBL), and will compare the two in the context of the secondary science classroom.

INQUIRY-BASED LEARNING

In science education, "inquiry" is a broad term that is defined in various, but similar, manners throughout current literature. In its most basic sense, inquiry is closely related to the idea of exploration, especially in regard to the phenomena of the natural world, "Inquiry…refers to more authentic ways in which learners can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science" (Hofstein & Lunetta, 2004, p. 30). The emphasis on understanding the "spirit of science" should be a crucial element of any science curricula, yet it is one that is often left out. If students are asked to achieve a complete understanding of the scientific spirit, and the classroom experience is solely a collection of isolated facts and theories, it is highly doubtful a true appreciation will ever emerge. However, when students are allowed to explore science, and are encouraged to ask the questions that pertain to their lives, a deeper understanding of the nature of science can be achieved (Songer, Lee, & McDonald, 2003).

While the above definitions provide a basic idea of how inquiry can be approached in the classroom, the method can be broken down into more specific steps, "Scientific inquiry is generally defined as a process of asking questions, generating data through systematic observation or experimentation, interpreting data, and drawing conclusions" (Sandoval & Reiser, 2004, p. 345). While this would seem to indicate that IBL is a linear process, with students proceeding step by step through the scientific method, this is not always the case as the steps can be rearranged depending on the need. Frequently, approaching inquiry learning as a linear process is referred to as the "hypothesis testing" model (Windschitl, 2003) since the students begin with a hypothesis or question and, through collection and interpretation of data, seek to prove or disprove that hypothesis.

Thus far, inquiry has been defined broadly, as an exploration into the "spirit of science" and more specifically as a 4-step method of questioning, gathering data, interpreting data, and drawing conclusions. However, there is one final and even more specific definition of inquiry provided by the NRC, which shows how vast and intensive the inquiry process can be,

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze , and interpret data; proposing answers, explanations, and predications; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (1996, p. 23).

While all of the definitions discussed so far offer a different take on what inquiry is and how it affects the classroom, there are strong commonalities among them. Arguably, the most important theme of inquiry learning, which appears in all of these definitions, is the necessity to actively engage students in the learning process. When students are involved in the learning process in this manner, they begin to see and build connections between ideas, learn to cooperate and function as part of a team, and, most importantly, begin to explore the world around them. "Such experiences offer students opportunities to consider how to solve problems and develop their understanding. Through collaborations, they can also come to understand the nature of an expert scientific community. These are among the learning outcomes now thought to be very important in introductory science" (Hofstein & Lunetta, 2004, p. 36).

The basic definitions of IBL have been addressed; therefore, the role of the teacher in this process must be elaborated on. In traditional methods of teaching, such as direct instruction, the teacher generally provides the information through lectures, discussions, presentations, etc., and the students learn or memorize that information in order to pass a test or complete an assignment. This approach differs greatly from IBL. In inquiry learning, the teacher tends to act as a facilitator or guide and less as an instructor. The teacher, and frequently the students, establishes what the main goal of an inquiry unit is, provides the resources for the students to achieve this goal, and then guides the students as they discover and develop their own unique conclusions. When questions arise about terminology, concepts, or methodology, the teacher provides assistance and helps guide the students to find their own answers.

From this explanation, it may seem as if IBL is very free-form and unstructured, but this is assuredly not the case. In order for an inquiry unit to be run successfully, there must be a large amount of structure and organization in place. The teacher and students should work together to develop goals and objectives as to what will be accomplished through the course of an inquiry unit. There must be checkpoints along the way to ensure that students are collecting accurate data, analyzing that data properly, and coming to sensible conclusions. While structure must be in place to ensure productive learning occurs, there is greater freedom in what and how the students learn than in traditional instruction.

In addition to instruction, there are also differences in assessment between IBL and traditional instruction. In traditional instruction, students are generally given a test or an assignment for which the teacher has an answer key and can grade each item as correct or incorrect, thus providing a grade based on student performance. With IBL, teachers must approach assessment in a different manner as the final products of an inquiry lesson can vary greatly. Students may give presentations, create posters, discuss trends and conclusions, compare similarities and differences between groups, and write papers. It may be that all of these options are available to students to choose from, and the teacher would be responsible for assessing, in an equitable manner, all of these varying final products. Therefore, teachers must necessarily establish well-defined learning objectives so that students know precisely what they will be assessed on before the inquiry unit even begins. Teachers may allow students to have some input into what these learning objectives will be, or they may decide on their own; regardless, students must go into an inquiry unit knowing what outcome is expected of them.

Unfortunately, when students are given a voice and allowed to contribute to the development of learning objectives, politics at the district, state, and national level may become a major deterrent. "In many schools, the pressure to perform well on high-stakes standardized tests crowds out teachers' ability to try more risky, in-depth inquiry science programs" (Songer, Lee, & McDonald, 2003, p. 491). As a result, many science programs only spend 2-3 weeks discussing the importance of inquiry, and rarely structure entire units or curricula around the principles of inquiry. Since most of the content in tested material is purely factual and not conceptual, many teachers feel they cannot prepare students for standardized tests and allow them time to explore and engage in IBL. However, it must be noted that traditional and inquiry-based methods can be, at least to some degree, blended together,

> Teachers need to *explicitly* address the reform-based goals related to knowledge *about* inquiry and the Nature of Science within instruction about "traditional" science content and process skills. This end is best accomplished by having students perform scientific investigations followed by reflection on these activities and the nature of the knowledge produced. "Explicit" in this context does not refer to *direct* instruction. Indeed, allowing students to come to the desired understandings on their own with the aid of carefully crafted experiences and reflective questions is a much more effective approach (Abd-El-Khalick, et al., 2004, p. 403).

By establishing inquiry learning within a traditional context, it is possible to meet the requirements of standardization and provide the students with educationally rich and engaging experiences.

PROBLEM-BASED LEARNING

Problem-Based Learning, like Inquiry-Based Learning, is defined in various ways throughout current literature. PBL was introduced to the educational scene over 30 years ago when it was first presented in medical school curricula because the pedagogical methods of the time were becoming increasingly ineffective (Savery, 2006, p. 9). In the broad sense, PBL is built around the idea that student learning occurs best when students are asked to solve real-world problems, "PBL is an appealing instructional strategy. Rather than reading or hearing about the facts and concepts that define an academic field of study, students solve realistic (albeit, simulated) problems that reflect the decisions and dilemmas people face every day" (Mergendoller, Maxwell, & Bellisimo, 2006, p. 49). Like IBL, PBL is learner centered and involves a great deal of student exploration into particular real-world issues. A more specific definition of PBL can also be provided,

> Features of PBL include initiating learning with an ill-structured problem, using the problem to structure the learning agenda, using the instructor as a metacognitive coach, and working in collaborative groups. Ill-structured problems are those where (a) the initial situations lack all the information necessary to develop a solution, (b) there is no single right way to approach the task of problem-solving, (c) as new information is gathered, the problem definition changes, and (d) students will never be completely sure that they have made the correct selection of solution options (Chin & Chia, 2004, p. 708).

This second definition includes the important addition that PBL must include "ill-structured" problems and defines the necessary criteria of those problems. One final definition of PBL more closely links this strategy to the inquiry methods described above, "[PBL] … is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006, p. 9). The steps outlined by Savery closely reflect the inquiry method's steps of asking a question, collecting and interpreting data, and coming to a conclusion. Due to the similarities of these two models, PBL is often considered to be one type of IBL, with IBL being the broader, more general method.

When designing a unit using the PBL method, the teacher must initially design a problem that will allow the students to explore a relevant issue while simultaneously meeting the learning objectives the teacher deems necessary. Assuredly, this is not an easy task. Fortunately, there are educational organizations that provide teachers with prefabricated PBL units, such as the Illinois Mathematics and Science Academy (ISMA); however, caution must be taken when purchasing premade units as transference of educational activities to a new setting is not always a smooth one. Teachers must always adapt premade units to fit the specific needs of their classroom and students, and this can often be an arduous task. If teachers do decide to create their own PBL units from scratch, they must have a firm grasp on the ability levels of students to know how to best divide the class into cooperative groups that will work well together, have a variety of ability levels and intelligences represented, and have at least one member who is willing to act as a group leader.

COMPARISON OF IBL AND PBL

There are many similarities between IBL and PBL instructional models. The idea of exploration is a major theme for both strategies as is the importance of creating a learner-centered classroom environment. Difficulties in using traditional forms of assessment (i.e. standardized tests) also arise in both IBL and PBL. For this reason, teachers often feel incapable of using the models and adhering to the stringent requirements of No Child Left Behind (NCLB) and the requirements of their districts and state. The additional similarities of these two models are discussed below as Savery introduces IBL and compares it to what he has already described about PBL,

> Inquiry-based learning is grounded in the philosophy of John Dewey (as is PBL), who believed that education begins with the curiosity of the learner. Inquiry-based learning is a student-centered, active learning approach focused on questioning, critical thinking, and problem solving. Inquiry-based learning activities begin with a question followed by investigating solutions, creating new knowledge as information is gathered and understood, discussing discoveries and experiences, and reflecting on new-found knowledge. Inquiry-based learning…encourages a hands-on approach where students practice the scientific method on authentic problems (questions).

Additionally, both models see the role of the teacher as one that is less active in the instructional process and more active in the creation of an exploratory environment. However, in regards to the role of the teacher there is a difference between these two methods as well,

> The primary difference between PBL and IBL relates to the role of the tutor. In an inquiry-based approach the tutor is both a facilitator of learning (encouraging/expecting higher-order thinking) and a provider of information. In a PBL approach the tutor supports the process and expects learners to make their thinking clear, but the tutor does not provide information related to the problem—that is the responsibility of the learners (Savery, 2006, p. 16).

This distinction is an important one to make, especially in regards to the workload of the teacher. For IBL, providing all the necessary information means that the educator must possess all the necessary information. Prior to the unit, the teacher must perform background research on the issue in order to be prepared to provide the students with anything they might need or, at the very least, be able to direct the students to where they need to go to get needed materials.

There is one final difference between these models that must be noted. IBL, being the broader and more general of the methods, can essentially be applied to any science-related topic, standard, or theory. PBL, on the other hand, can only be used in specific instances in which a real-world problem is at the heart of the unit. As an example, for the topic of electricity, an IBL activity could be something as broad as giving the students a battery, light bulb, and wire, and letting them explore the possibilities on lighting the bulb. In contrast, a PBL activity would present an issue such as a power plant's distributing electricity. The students' response should be a potential solution to that problem. Therefore, IBL is considered the more general, overarching form of inquiry learning, as it can be applied in multiple contexts, while PBL is considered a more specific model as it has stricter criteria that must be followed.

CONCLUSION

There are many benefits of integrating Inquiry-Based Learning and Problem-Based Learning into today's classrooms. Students become more active in the learning process, form more connections between science concepts and real-world applications, and above all, students take part in an investigation and exploration of the world around them. While the primary focus of this paper has been on using inquiry methods as instructional strategies, an interesting point can also be made on the necessity of approaching the art of teaching as an inquiry process as well, "teaching is regarded - at least in part - as a form of inquiry, as a process of exploring problems that one cannot always define or predict" (Eisner, 1994, p. 163). When inquiry, and the ideas associated with inquiry such as exploration, is linked to teaching, an exciting view of pedagogy emerges. If teachers approach their craft with the idea of exploration in mind, that they are on a journey or quest to find the best ways possible to deliver the material that is most beneficial for their students, they will find the classroom and their role in it a much more invigorating and inspiring one.

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