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How Can True Inquiry Happen in K-16 Science Education?

In his analysis of current research on teaching through the use of inquiry in the science curriculum, the author explores student learning, students' misconceptions of the nature of science, and ideas for curricular support, as components of the challenge teachers must face when implementing an inquiry curriculum.

In my nearly 20 years of high school and undergraduate college instruction, I have implemented many inquiry assignments. Inquiry instruction has been an effective method for creating a context that allows my students to better understand concepts through the processes of engaging in scientific research. In my prior attempts to integrate inquiry-based learning opportunities into the curriculum, my students consistently responded with numerous questions, confusion, frustration, and/or lack of motivation to learn. Yet, I persisted in use of inquiry-based instruction, because I perceived that there was something to be learned from engaging in the scientific process.

Initially, I attributed negative student reaction to inquiry assignments as a lack of initiative. Nevertheless, I wondered if anything else could possibly explain my lack of success. The wisdom and philosophy of Dewey (1938) suggests that providing my students a supportive environment and the freedom to construct their own knowledge would motivate them to become engaged learners. In practice, I have found this response to be rather atypical. I asked my students to explain their lack of excitement for inquiry-based assignments and their reluctance to engage in the creative and authentic research opportunities that I had arranged for them. The students responded that they did not know what to do.

It took some time experimenting with this approach, but I have determined that the kind of inquiry that I want for my students is a complex process. Although inquiry appears to be a promising method for effectively conveying scientific principles, it unavoidably requires more prior knowledge and experience than typical high school or college undergraduate students have at their disposal (Settlage, 2007). Despite this limitation, there is an expectation that science teachers will engage students in inquiry-based instruction. This is further confounded by the wide range of perceptions of the definition of inquiry and the processes associated with it (Buck, Bretz, & Towns, 2008; Chinn & Malhotra, 2002). This has resulted in a diverse range of educational activities and lessons that are promoted as scientific inquiry. With this in mind, I considered the possibility that the form and structure of my inquiry-based assignments contributed to a lack of student enthusiasm.

The integration of scientific inquiry into the curriculum is closely aligned with the philosophy of constructivist learning, which asserts that students construct knowledge and develop deeper understanding through experience.

The expanding emphasis on inquiry in science education has motivated me to examine other views and experiences with this instructional approach. In addition, I have reviewed research investigating the effect of inquiry-based instruction on student engagement in learning, on their acquisition of content knowledge, and on development of research skills. In this article, I begin with a discussion of the definition of inquiry and the reasons that it is being promoted in the science curriculum. I have integrated into this discussion an exploration of student reactions to inquiry in order to support the argument that authentic inquiry requires expertise that is absent in most high school and undergraduate students. I then explain the ways in which a scaffolded approach allows inquiry-based assignments to be presented in a manner that increases student productivity and success. I conclude with suggestions for future research concerning the use and effectiveness of inquiry as a method for learning and teaching science.

What is Inquiry?

Inquiry is the processes and activities that expert researchers engage in during authentic scientific investigations, or, simply stated, it is the process of doing science (Chinn & Malhotra, 2002; Duschl & Grandy, 2008). Scientists and other professionals actively engage in inquiries as they explore various aspects in their domains of interest (National Research Council [NRC], 1996). Although it is argued that scientific research does not involve one specific scientific method (McComas, Almazroa, & Clough, 1998), there are similar steps and procedures found within most scientific investigations.

The National Research Council developed a definition of inquiry as a component of the *National Science Education Standards* (NSES) (NRC, 1996). The NRC defines inquiry as:

> *The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p. 23)*

This definition reveals the approach to scientific investigations that professional researchers consider the most effective. This definition also makes clear that student engagement in inquiry is considered to be an instructional method for learning scientific principles. However, examinations of published science curricula that claim to provide inquiry instruction to help students meet the NRC goal to "*develop knowledge and understanding of scientific ideas*", reveal diverse perspectives concerning activities that involve inquiry (Buck, Bretz, & Towns, 2008; Chinn & Malhotra, 2002). I embrace a pragmatic perspective which maintains that inquiry should have the detectable presence and implementation of three essential elements: research question(s), methodology and data collection, and the interpretation and explanation of results (Schwab, 1962; Herron, 1971). Additionally, I argue there is justification for a fourth element involving the evaluation of the validity, plausibility, and credibility of research results. However, for the sake of discussion, I will use the three element perspective contained within Schwab's model of inquiry.

Using the model proposed by Schwab (1962), student and teacher engagement in an inquiry can generally be classified into one of four levels. This four-tiered classification scheme is based on the extent to which the student, as opposed to the teacher, is responsible for each of the three essential elements. The level of inquiry increases from 0 to 3 as the responsibility for the various aspects of the research shifts from teacher (or curricular sources) to learner (see Figure 1). At Level 0, the student is provided with the research questions, methodology for gathering data, and the approach for interpreting the data. By Level 3, the student is working almost independently and is responsible for all three inquiry elements.

It is apparent that students engaging in Level 0 or 1 inquiry activities are most likely following prescriptive procedures with little resemblance to authentic scientific research. However, in order to engage in authentic Level 3 research, students must assume a high level of responsibility for research activities, and they must possess an understanding of the complexities and variations associated with conducting original investigations. These conditions illustrate a paradox that arises during inquiry instruction.

Here is the nature of the paradox: students engaging in the prescriptive inquiry activities of Level 0 and 1 are likely able to complete these activities without difficulty, but they are also apt to develop the perception that scientific research is the process

Figure 1: Schwab's Levels of Inquiry (Schwab, 1962)

Inquiry Level	Source of the Question	Data Collection Methods	Interpretation of Results
Level 0	Provided	Provided	Provided
Level 1	Provided	Provided	Open to Learner
Level 2	Provided	Open to Learner	Open to Learner
Level 3	Open to Learner	Open to Learner	Open to Learner

of following established, precise steps to achieve a predetermined solution (Chinn & Malholtra, 2002). However, if students engage in the scientific activities of the authentic inquiry represented by Schawb's (1962) Level 3 inquiry, their lack of experience is likely to be overwhelming, leaving them unable to successfully complete these assignments. This may cause students to develop the perception that scientific research is inaccessible (Edelson, 1998). Simply stated, if the inquiry is attainable for students, it will most likely be superficial, but if the inquiry is substantial, then it will most likely be unattainable. If inquiry methodology is to be considered useful for science instruction, then we need to find an effective solution that resolves this paradox.

Inquiry in the Curriculum

The integration of inquiry into the science curriculum is founded on the conjecture that student participation in these assignments will lead to an increase in their knowledge of the concepts and processes of scientific investigations, as well as the nature of science (Abd-El-Khalick et al., 2004; Driver, Leach, Milar, & Scott, 1996; Llewellyn, 2002; NRC, 1996). Simplified, there is the expectation that by actively engaging in scientific activities students will learn scientific principles. The integration of scientific inquiry into the curriculum is closely aligned with the philosophy of constructivist learning, which asserts that students construct knowledge and develop deeper understanding through experience (Kirschner, Sweller, & Clark, 2006; Lewis, 2006, NRC 2000). Some perspectives of constructivist instruction maintain that learning is most effective when learners are prompted to ask questions and are provided with the opportunity or context necessary to answer those questions (Dewey, 1938). Since the 1960s, efforts to create constructivist ecologies have produced several curricular variations, which include problem-based learning, discovery learning, and inquiry (Kirschner, Sweller & Clark, 2006).

Perhaps the greatest obstacle impeding the effectiveness of inquiry instruction is the limited experience and prior knowledge of students.

It is possible for methodologies that incorporate the principles of problem-based learning, discovery learning, and inquiry, to use similar instructional approaches in order to engage students in active, participatory learning (Kirchner et al., 2006; Savery, 2006). Depending on the learning goals and abilities of the student, the process and procedures of these approaches may take on marginally different appearances (Lewis, 2006; Savery, 2006). All three of these approaches encourage learners to pose questions, develop hypotheses, design experiments, gather data, interpret results, draw conclusions, and form theories (Audet & Jordan, 2005; Kirschner et al., 2006; Lewis, 2006; Llewellyn, 2002; Mayer, 2004). The anticipated learning outcome is greater understanding of concepts, acquired through the process of answering self-generated questions and solving associated problems.

Inquiry-based methodology has become an emphasis in science education standards, because it is predicted that engaging in authentic research will enable students to learn about the nature of science, the scientific process and research procedures, as well as to gain science concept knowledge (Abd-El-Khalick et al., 2004; Driver et al., 1996; Llewellyn, 2002; NRC, 2000). However, as Anderson (2002) points out, "inquiry means different things to different people" (p. 3). Thus, Anderson recognizes the variability in the way that teachers, researchers and curriculum developers interpret and use the concept of inquiry. Diverse approaches to inquiry instruction and the corresponding variations in expected learning outcomes is further evidence of the diverseness promoted by inquiry-based instruction (Buck, Bretz, & Towns, 2008; Chinn & Malhotra, 2002). Thus, definitions of inquiry may be perceived to be relative, influenced by the source of the inquiry, the levels of experience and perceptions of those involved in the instructional process, as well as the desired learning outcomes. In my early attempts at inquiry instruction, I was fully committed to approaches that utilized the definition of inquiry as: *the processes engaged in by professional researchers*, which could be considered to be Schwab's (1962) Level 3 inquiry. I anticipated that this approach would increase opportunities for my students to learn about authentic research, and would resolve the perceptions that research was similar to the prescriptive structure of canned laboratory exercises that they had previously encountered in their science education. However, my students' learning outcomes were not consistent with my expectations. They were overwhelmed and were not learning from the process. By balancing my expectations with a desire to engage my students in authentic research opportunities, over time I was able to modify my expectations to fit the readiness of my students to actively engage in inquiry activities.

Influences on Inquiry Engagement

Variations in student learning through inquiry-based activities reveals many challenges (Anderson 2002; Chinn & Malhotra, 2002; Echevarria 2003; Kaartinen & Kumpulainen, 2002; Keys & Bryan, 2001; Kirschner et al., 2006; Lewis, 2006; Marx et al., 2004; Roehrig & Luft, 2004a, 2004b; Roehrig, Luft, Kurdziel, & Turner, 2003; Sandoval, 2005). Some of this research reveals outcomes similar to those I have experienced. That is, they report that authentic inquiry instruction led to increased levels of student frustration due to lack of direction combined with incomplete or inaccurate conceptual development. Due to the correlation between attitude and retention, student attitudes concerning inquiry-based activities must be considered when evaluating the challenges and complexities associated with this instructional technique. The reported results from investigations of authentic inquiry instruction are relatively the same for high school students and undergraduate college students.

Perhaps the greatest obstacle impeding the effectiveness of inquiry instruction is the limited experience and prior knowledge of students (Anderson 2002; Kaartinen & Kumpulainen, 2002; Keys & Bryan, 2001; Roehrig et al., 2003; Sandoval 2005). Results from investigations that examine learning through inquiry expose the critical influence of prior knowledge and experience on the instructional success of inquiry-based instruction (Mayer, 2004). Wolpert (1997) contends that the ability to apply problem-solving techniques to commonplace situations and the ability to scientifically problem solve do not necessarily overlap. Wolpert maintains that the knowledge necessary for effective participation in scientific investigations is highly specific and relates to awareness and familiarity of work accomplished by other scientists. It is unreasonable to expect students to have this knowledge, experience, and awareness. Therefore, we should anticipate that novice learners will exhibit a limited ability to successfully carry out authentic scientific inquiry.

Authentic inquiry, pure discovery, and problem-based learning require a tremendous amount of mental effort even for an expert researcher.

Authentic inquiry, pure discovery, and problem-based learning require a tremendous amount of mental effort even for an expert researcher (Schoenfeld, 1987). Kirschner et al., (2006) argue that considerable background knowledge and experience are essential to the complex problem-solving required for accomplishing authentic inquiry. Thus, authentic inquiry lessons and activities (Schwab's Level 3) require novice learners to perform expert functions, which they typically are not equipped to perform (Kirschner et al.; Schoenfeld, 1987).

In my attempts to engage my students in authentic inquiry activities, I frequently neglected the extensive skill set that is required for successful completion of research. I expected that my content instruction and the examples I had provided through structured labs (Schwab's Levels 0 and 1) would prepare my students with the knowledge and experience necessary to engage in independent inquiry. This expectation was not met, because in addition to content knowledge and knowledge of the scientific process, authentic inquiry also requires the participant to utilize advanced metacognitive skills. The necessary skills are those associated with complex problem-solving, posing researchable questions, and determining fruitful approaches for gathering pertinent evidence (Schoenfeld, 1987; Wolpert, 1997). My students had not yet mastered all of these skills. In order to compensate, I try to keep in mind the idea that learners rely on prior knowledge to productively solve problems while simultaneously acquiring new knowledge through experience (Bransford, Brown, & Cocking, 1999). Thus, when determining the level of sophistication and structure of inquiry activities appropriate for a particular class, the instructor should begin by assessing the cognitive and metacognitive abilities of the learners, as well as their prior knowledge. The instructor should then choose activities that build on these capabilities and perspectives.

Inquiry and Misconceptions of the Nature of Science

Widely differing views pertaining to the nature of science (NOS) and the structure of scientific knowledge accentuate the differences between the perspectives of professional scientists and novices (McComas, 1998). According to the scientific perspective of knowledge, hypotheses are predictions and explanations based on evidence, theories are explanations based on evidence, and scientific laws are measurable constants. The naïve conception that scientific knowledge evolves from hypothesis, to theory, and progresses through the accumulation of evidence into scientific law is well documented among novice learners (Driver et al., 1994; McComas, 1998; Miller, 2008). This common misconception regarding the nature of science constrains the ability of the learner to understand the process of scientific advancement through inquiry, because it gives the impression that knowledge is goal-oriented. These misconceptions can lead learners to develop additional NOS misconceptions, such as the notion that scientific endeavors are guided by a distinct set of prescriptive procedures used to determine ultimate truths (Chinn & Malhotra, 2002; McComas, Almazroa & Clough, 1998; Trumbull, Bonney & Grudens-Schuck, 2005).

Previous research indicates that professional scientists, educators, and students hold vastly different views of knowledge (Chinn & Malhotra, 2002; Schoenfeld, 1987). Therefore, individuals from these different groups are likely to use different approaches when participating in inquiry-based activities (Anderson, 2002; Chinn & Malhotra, 2002; Hakkarainen, 2003; Keys & Bryan, 2001). Common student misconceptions, such as the belief that scientific methods are a rigid set of research steps and the belief that knowledge is absolute and consistent, create significant barriers to effective engagement in inquiry activities (Chinn & Malhotra, 2002; Hakkarainen, 2003; Marx et al., 2004; Sandoval 2005). The misguided belief that knowledge is absolute and that therefore the goal of science is to discover ultimate truth often causes students to expect to find the one right answer to questions or problems rather than to exclude possibilities in an attempt to arrive at one of many possible solutions (McComas, 1998). Further, student participation in structured lab activities typically associated with Schwab's (1962) Level 0 or 1 inquiry may actually reinforce these misconceptions. When students engaging in traditional lab exercises encounter results that fall outside of the expected outcomes, they tend to apply their misconceptions (Schneps & Sadler, 1988, 1997) or simply conclude that they made a mistake, rather than seek deeper explanation. Because common student misconceptions typically impede their motivation to seek explanations for variations in inquiry outcomes, (Bruning, Schraw, & Roming, 1999) they are unlikely to uncover and understand more complex aspects of their research practices that may be contributing to the observed anomalies.

In summary, common student misconceptions limit the ability of novice learners to effectively engage in scientific inquiry through the application of problem-solving strategies. Placing novice learners in authentic inquiry environments without structured and targeted support can increase frustration and decrease learning. This ineffective strategy could have the long-term result of causing the learner to develop a general dislike for science. Therefore, I have found that for inquiry to be an effective instructional approach, it must be implemented in a manner that guides students through the obstacles they face while engaging in the scientific process.

Adapting to Learners – Guided Inquiry

The barriers limiting student learning with inquiry instruction suggest that teachers should use a technique that scaffolds (Vygotsky & Cole, 1978) the process by providing guidance at critical points during investigations and partitioning the overall process into attainable elements (Mayer, 2004; Palincsar, Collins, Marano, & Magnusson, 2000; Polman & Pea, 2001). Scaffolding instruction can account for factors that limit student success by guiding students through inquiry processes using a step by step approach (Vygotsky & Cole). Even though guided inquiry is effective in teaching students about scientific research, Buck, Bretz and Towns (2008) report that this instructional approach is rare in most science curricula, including undergraduate science programs. Buck and colleagues report that the vast majority of lab activities utilized in undergraduate science curricula are structured to provide Level 0 or 1 experience. The lack of sufficient guided inquiry experience available in post secondary education is critical, because most K-8 teachers may never receive additional exposure to authentic inquiry processes. Therefore, they are unlikely to pass them on to their students (Deemer, 2004; Llinares & Krainer, 2006).

Direct instruction and structured learning, advocated by Kirschner et al. (2006), assist novice learners in acquiring the knowledge necessary to productively engage in increasingly independent problem solving activities. Kirschner et al. argue that direct instruction is the most efficient way for students to acquire knowledge and develop expert skills. Although this approach may be effective at conveying knowledge of content material and addressing student misconceptions regarding the nature of science (Bransford, Brown, & Cocking, 1999), I have determined that direct instruction does not effectively lead to the development of student problem solving abilities, nor does it increase student understanding of inquiry and the scientific method. I have found that in order for inquiry instruction to be most effective, it is necessary to first identify learning barriers that hinder active engagement. Then it is possible to use guided inquiry activities teachers to expose students to models of research, laboratory practice and motivational learning opportunities that enable students learn through exposure to the complexities of authentic scientific investigation, thereby developing critical thinking and problem solving skills (Bransford et al., 1999; Bruning, et al., 1999).

Scaffolding Inquiry

A more effective instructional technique for developing inquiry skills involves scaffolding inquiry activities for students (Sandoval & Reiser, 2004; Vygotsky & Cole, 1978). Implementing inquiry curricula and instruction in which students learn and engage in guided research assignments that are detailed, scaffolded, and supported, will increase the chance of successfully acquiring the targeted knowledge while preparing them to be increasingly independent learners. Bransford and colleagues (1999) argue that careful planning, exposure to prior examples, continuous assessment, and constructive feedback are essential for preparing students to independently engage in complex learning activities. In addition, a scaffolded inquiry

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approach provides opportunities for teachers to directly address misconceptions regarding the nature of science and the scientific process as they pertain to the particular subject matter under discussion.

I have developed, used, and continue to use scaffolded inquiry assignments with high school, undergraduate and graduate students. Even though I have not formally investigated its effectiveness, my experience indicates that the scaffolding process allows my students to achieve much higher levels of success than cases in which students are expected to complete inquiry assignments individually without support. I begin my scaffolding process by providing students with an outline of the various processes and components required of their inquiry assignment. This outline is a decomposition of all the elements typically associated with a scientific inquiry, and it is accompanied by a timeline and instructions for completing different aspects of the overall assignment. My intention is to guide my students through the inquiry process by leading them slowly toward the development of a final outcome, while allowing for independent investigations. The process of scaffolding aids the students by reducing the perceived extent of complexity associated with conducting an inquiry, thereby reducing anxiety and allowing them to focus on specific achievable outcomes. I have observed that scaffolding one inquiry assignment does not necessarily transfer well to additional inquiry assignments. Even so, students do benefit from exposure to models of authentic research, and this has been very effective for each particular inquiry assignment. Through repeated use of scaffolded inquiry assignments, students may begin to develop the metacognitive skills necessary to begin transferring knowledge gained to additional concepts. The following is an example of how I utilize a timeline, an outline of the expected student products at each stage, and a list of final expectations to develop a scaffolded inquiry-related classroom activity.

An Example of Scaffolded Inquiry

The primary goal of my inquiry assignments is to increase student understanding of authentic research and the different steps involved in conducting and reporting investigations. My example is from an assignment that I designed to provide students the opportunity to apply data analysis techniques that were discussed throughout a semester course. The crux of the assignment involves student selection of an area of personal interest, development of associated research questions, conducting the investigation and reporting the results.

My students have proposed and conducted a diverse range of creative research projects. These investigations have examined: the physical parameters of different varieties of apples, pine cone dimensions in relationship to the number of scales, the effect of different amounts of baking soda on the height of cooked muffins, the time required for seed germination at various temperatures, the height of a golf ball bounce at different temperatures, the relationship between tree branch circumference and its length from the trunk, and many other unique ideas. These investigation topics were generated from discussions, brainstorming, and examination of prior research. Many of these ideas were suggested by students, and others projects came about as a result of suggestions and guidance on my part. The encouraging of students to select topics of individual interest helps to promote active participation in the inquiry assignment.

Once the inquiry project has been assigned, I provide a timeline that corresponds to the task to be completed (see Table 1). I have found that using a timeline to walk students through the major components of the project is an effective way of scaffolding the inquiry assignment. Through scaffolding, I have been able to guide students through the inquiry process by breaking inquiry assignments into achievable chunks that allow students to effectively work on independent inquiry projects. My inquiry assignments typically take place over two week periods, and much of the student work occurs outside of scheduled class time.

Along with the timeline and task table (Table 1), I also provide students with the details of the assignment criteria (see Figure 1). The assignment criteria will include descriptions of the purpose, procedure, and guidelines for the inquiry project. Note that the assignment also includes additional details of the contents expected in the final report and that these correlate directly with the tasks in the timeline table. Through the combination of these materials, I am able to address the need for structure and guidance as my students engage in independent inquiry activities.

Table 1: Time Line and Task for Completing the Inquiry Assignment

Day	Inquiry Task to be Completed
1	Select a topic for study, justify the choice
2	Provide at least 2 references and develop a proposal for further research
4	Gather data (at least a sub set of your final data set)
6	Hypothesis statements and analysis methods
8	Analysis and interpretation of results
10	Poster completed, Presentation of Research

All of the aspects of authentic inquiry are present in my assignments, starting with posing questions and concluding with publication and sharing results. I know that it is important for my students to learn about research by engaging in activities that are as close to authentic research as possible to bring further meaning and context to my assignments. I also integrate direct instruction to address common misconceptions of the nature of science and of other content that may hinder or limit student ability to successfully complete the inquiry process. By utilizing scaffolding to promote participatory learning and direct instruction to address possible conceptual barriers, I am able to produce a situation that has a high level of success in increasing student understanding through the use of inquiry assignments.

Future Research

During my more than 20 years in education, I have seen some excellent ideas and programs discarded or disregarded because they were not well supported or understood. Likewise, I have seen some very questionable attempts at educational reform embraced enthusiastically without any evidence to indicate that they increase student knowledge or aid in learning. Therefore, I think it is critical that we investigate instructional approaches prior to promoting their implementation, inquiry notwithstanding. It is apparent from my personal experience and the research of others that inquiry is a complex process that is limited by student experience, knowledge, and misconceptions. Despite this, the promotion of inquiry as an instructional method for learning science is clear and consistent. Therefore, if inquiry-based methodologies are going to be promoted as an approach for teaching science, we need empirical support to make evident which of the corresponding instructional strategies are the most effective techniques for successfully imparting knowledge of science, problem-solving, and research.

I have outlined a method for increasing student engagement in inquiry activities; yet, I do not have the empirical evidence to support my proposition that this increases student learning or understanding of scientific investigations. If inquiry is to be used as a method, we should have the evidence to support how and why it increases student knowledge of the content and processes of science. If inquiry approaches do not increase student knowledge, then we need to consider alternatives or modifications, such as integrating instructional techniques that have been determined to be effective, for example, scaffolding and continuous assessment. Although I advocate engaging students in independent science research, I am also practical in my philosophy that educational activities should increase student learning and that evidence is required to explain and support anticipated learning outcomes.

Figure 1: The criteria for an inquiry assignment which required students to gather unique data and apply appropriate statistical methods.

Using Statistics

Purpose: The purpose of this project is to provide you with an opportunity to apply the knowledge that you have gained throughout the semester to an authentic research project. It is an opportunity to gather your own data and conduct meaningful scientific investigations and communicate the process and results in a poster presentation.

Research: You may gather data for any situation that you would like, provided it meets the guidelines below. This project is a ***significant*** part of your grade; therefore, it is expected that your final product will be of high quality.

Guidelines: To begin this project, you are to submit a proposal for your research project, outlining what you plan to study and how you plan to study it. Once submitted and confirmed, you are to collect data that is original and does not belong to someone else. Once data collection is complete, you will develop your report as a poster to include the following:

- Title
- Name/Date
- Background – with at least 2 references
- Hypothesis
- The data and how it was collected
- Results
  - Descriptive Statistics
  - Plots with appropriate labels
  - Test Statistic
- Analysis
- Implications

This is to be assembled into a poster which will be evaluated according to a project rubric. This is a major component of your coursework and therefore, a strong emphasis will be placed on both the quality and depth of your work.

Abstract: In addition to the poster – which you will keep, I would like an abstract of your project – which I will keep. This is a ½ page summary of the entire project (no more than one page, approximately 250-500 words). I will collect the abstracts and keep them along with the scoring rubrics for verification of your work on this project.

Data: A reasonably sized sample of original data you collect - usually at least 30 events.

Analysis: You may use any of the hypothesis testing analysis techniques that we cover in the course, but you must use at least one.

Presentation: You will present your poster in a brief presentation (no more than 10 minutes) to the class during finals week.

Conclusion

Inquiry is viewed as a method of engaging learners in scientific investigations by exposing them to the processes used by professional researchers, in order to increase student comprehension of science content and methodology (Carlson, Humphrey, & Reinhardt, 2003; Echevarria, 2003; Llewellyn, 2002). However, the limited prior experience of students and common misconceptions as to the nature of science may greatly limit the likelihood that students will benefit from inquiry activities without substantial support and instruction (Kirschner et al., 2006; Kuhn, 1997; Mayer, 2004). These barriers necessitate teacher implementation of modifications and additions to inquiry instruction in order to assure success in student learning.

Direct instruction resolves some of the issues of limited experience and knowledge. An instructor may improve student understanding of science by directly addressing misconceptions. Yet, direct instruction does not provide experience by actively engaging students in research activities. Therefore, other techniques such as scaffolding (Vygotsky & Cole, 1978) should be used in conjunction with direct instruction. This would provide experience with inquiry and enable students to develop the skills and knowledge required to engage in independent activities.

Many advocates for inquiry methodologies expect that students will be able to successfully engage in the complex processes of inquiry that often take experts years to develop. This expectation is frequently not met, and it must be addressed as a significant issue associated with the promotion of this pedagogy. At the time it is necessary to bear in mind that lower levels of inquiry are unlikely to teach students how authentic research is actually conducted (Chinn & Malhotra, 2002). Both teachers and students need support in comprehending the inquiry processes, and they should be guided through numerous examples before they can effectively and productively engage in exercises that will lead to the processes found in authentic scientific research. There is a need to investigate the effectiveness of different approaches of inquiry-based methodologies in order to determine if there are more successful ways of increasing student comprehension of science content and understanding of scientific research. Students learn more about science through active participation in scientific practice, but, effective use of science practice activities requires that appropriate concessions be made to the needs, experience, and capabilities of the students involved.

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