Scientific Inquiry and the Impact on Classroom Environment

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Abstract: Scientific inquiry is an instructional strategy that requires students to engage in scientific problem solving by identifying a problem, designing an investigation, and supporting conclusions with evidence. The demand for the use of inquiry in the classroom is shown by the number of national and state standards that include inquiry as a requirement. Depending on the topic, inquiry in the classroom can range from structured to open. A classroom that engages in scientific inquiry creates an environment where students feel confident taking risks, collaborating, supporting conclusions with evidence and considering different positions. This article examines the foundations of scientific inquiry and the benefits to learners who are in a classroom where it is used.

Introduction

Austin, a high school sophomore, signed up for biology because his guidance counselor told him that he needed to pass the course to graduate from high school. Austin works at a local fast-food restaurant after school for about 20 hours a week. Both of his parents work full time, in fact, his dad works two jobs so he does not get to spend much time with him. Austin's mom works a job where her shifts vary, so sometimes she is not home at night and Austin has to help take care of his little brother.

Austin has never liked science very much because it seems like a collection of random facts to memorize. In all his other science classes, the teacher had given him notes, handed out a worksheet, and then given a test on Friday. Sometimes they did labs, but these always involved simply following directions, step-by-step, and he rarely the connection to what he was learning in class. He had never really done well in his other science classes – in fact, he had to attend summer school to pass his freshman science class. There did not seem to be much about science that related to his life, so he felt disconnected from the content and was indifferent to the learning. Austin was not looking forward to taking biology; honestly, he was hoping it would be the last science class he would ever have to take.

However, once he began biology, he knew this class would be different. This year, his teacher did not spend the entire class period lecturing and handing out worksheets. Instead, she asked what he wanted to know about the topics he was learning about. She had him come up with questions that he wanted answered and had him find the answers. He finally got a chance to research and explore ideas that he wanted to, for example how DNA is used in solving crimes. And he finally saw a connection between the labs and activities that he did in class and how the learning related to his life. For the first time, he actually looked forward to going to science class. In fact, he even made some new friends!

One of his favorite activities was during the unit on DNA technology and genetically

modified organisms (GMOs). His teacher asked the students in his class to research GMOs more and take a stance on if they supported their use or not. Once they took a side, they had to construct a product (it was their choice – a presentation, a video, a poster, or another visual aid) that showed their position and the evidence they found. They had a day in class where they had a debate and they had to consider the other side's findings and evidence. It was one of the first times that Austin felt like he was walking away from science class with information he could use in the real world.

The National Research Council (NRC) (2000) has pointed out that "traditional" science education, which treats science more as a set of facts to memorize rather than a way of learning, fails to prepare students for experiences in the real world because its lack of connection to their lives. This seems to be the approach in many science classes. The use of scientific inquiry to guide classroom instruction is a more student-centered approach. For many students, using scientific inquiry in the classroom sparks new interests and awakens a natural curiosity about scientific phenomena not felt before. The foundations of inquiry require opportunities for students to engage in exploration to construct and communicate understandings of scientific ideas.

Scientific inquiry helps students to develop an evidence-based opinions about socio-scientific issues, such as genetically modified organisms (GMOs). These are the same issues that current high school students will have to make decisions about as adults. And using scientific inquiry works to even the playing field for students and can create a healthy classroom environment where students work together to develop scientific explanations. For inquiry-centered learning to succeed it is vital that the classroom be a place where students feel comfortable communicating and working with both the teacher and their peers. In turn, a classroom that engages in scientific inquiry creates an environment where students feel confident taking risks, collaborating, supporting conclusions with evidence and considering different positions.

Cornerstones of Scientific Inquiry

The use of scientific inquiry in the classroom is reinforced by several education standards. The Next Generation Science Standards (NGSS) (2013) and Ohio's Revised Science Standards (2011) each include specific sections of the value of scientific inquiry in science education. In an official position statement, the National Science Teachers Association (NSTA) (2004) encourages science teachers at all levels to incorporate scientific inquiry as a regular activity in their classroom. The NRC (2000) released an entire book, Inquiry and the National Science Education Standards: A Guide for Teaching and Learning, to help teachers bring inquiry into their classrooms. The national push for inquiry has encouraged many teachers to embrace the power of inquiry within their classroom.

Scientific inquiry has been defined by the National Science Education Standards "as a pedagogical method that models scientific practice and encourages students to gain content knowledge" (as cited in Banjeree, 2010, p.1). According to the NGSS (2013), students need to be able to engage in the following practices in order to use scientific inquiry:

1. Asking questions.
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations.
7. Engaging in argument from advice.
8. Obtaining, evaluating, and communicating information. (Appendix F, p. 1)

Inquiry incorporates the nature and process of science so that students learn to think in the same way that a scientist in the field would to seek answer to a question (NRC, 2000). Although the steps presented appear sequential, it is important to point out that not every investigation needs to follow each step in a specific order (NSTA, 2004). Some investigations will require more revision than others and perhaps even repeat steps. Throughout the course of their educational career, students should have the opportunity to explore and improve these skills to prepare them for their next step in scientific discovery.

What Can Teachers Do?

Inquiry can take on many forms in the classroom based on the level of direction presented by the teacher. For inquiry to be considered "open," the students must dictate the direction of the investigation. They define questions, develop investigations, and determine materials (NRC, 2000). In these types of investigations, teachers take a much more supportive, facilitating role to allow students to construct and communicate explanations. In this case, students can arrive at the same conclusion through many different approaches – and therefore get to choose the path of their explorations. On the other end of the spectrum is guided inquiry. Guided inquiry allows teachers more control over questions students explore – teachers often determine materials and sometimes procedures for guided inquiry (NRC, 2000). In this case, the teachers might have a specific conclusion in mind so activities are geared towards helping students discover this. Teachers can also decide to use a mixture of these methods as students participate in student inquiry. For example, a teacher may determine the question (such as "Are GMOs safe to use?"), but allow the students to determine the materials and procedures they will use to find a conclusion. Teachers can also allow students more freedom in the questions asked and procedures utilized, but the teachers must then require that communication of discoveries be in a specific format – such as a lab report.

Inquiry allows for teachers to inspire curiosity in students while still maintaining some control of classroom activities and course pacing. In their official position statement on inquiry, the NSTA (2004) lists many recommendations for teachers on how they can help students to understand inquiry such as understanding that not all

questions can be answered by the same type of investigation. The most important thing that teachers can do when using inquiry is to ensure that students are active participants in their learning and that they are forming their own conclusions supported by evidence they accumulate during their investigation.

Benefits to Learners

Classroom Environment

A classroom that supports inquiry is a place where students feel confident taking risks because teachers place importance on student ideas and findings. In classrooms where inquiry takes place, teachers understand that students come with prior knowledge and experiences, and because the focus is on the learner, these experiences are valued (NRC, 2000). Perhaps the most significant impact that inquiry has on a classroom is the development of a community. In his poignant discussion of emotional ecology, Zembylas (2007) points out that "teachers and students create the environment that shapes how they are emotionally connected and engaged in learning together" (p. 357). Using inquiry can help to form these bonds between teachers, students, and content. In a classroom where inquiry is practiced, students understand that they can not only learn from the teacher, but from each other as well (NRC, 2000). The NSTA (2004) recommends that teachers "design and manage learning environments that provide students with the time, space, and resources needed for scientific inquiry" (p. 2). Such inquiry helps to develop a classroom where students feel safe interacting with each other as well as the teacher.

Collaboration

One of the most valuable and important results of using inquiry in the classroom is that students learn ways to communicate ideas with others during collaboration. In order for this to happen, the classroom needs to be a place where students feel comfortable presenting new ideas and taking risks, as well as asking questions and participating in dialogue and discussions: "Inquiry requires students to be positively interdependent, so that the benefit to one student benefits the whole group" (as cited in Wolf & Fraser, 2007, p. 324). This resonates with the idea of Zembylas (2007) that learning occurs when teachers and students work together. The community that is created from inquiry recognizes that communication and collaboration with others is a requirement to reach a deeper understanding of material.

Supporting Conclusions with Evidence

One of the cornerstones of inquiry is that students must support and defend conclusions with evidence. "It is not the K-12 teachers goal to create philosophers of science. The goal is to develop informed citizens so decisions can be made concerning personal and societal issues that are scientifically based" (Lederman, Antik, & Bartos, 2014, p. 291). A variety of issues that students will face in adulthood are controversial: for example, genetic engineering and climate change. Students will have to make decisions about these issues and these decisions will require evidence.

The NSTA's official position statement Teaching Science in the Context of Societal and Personal Issues (2016) offers several declarations for what students should learn about these complex issues facing the world today. The last statement sums up the importance of evidence-based approaches: "Prepare students to become future citizens who understand science and engineering and are willing to engage in making responsible and informed decisions" (p. 2). As students work through the process of inquiry, they develop a greater understanding of science by supporting their ideas with results from investigations. This one of the most important skills that inquiry helps develop because it allows students to be well versed in using evidence when making decisions.

Considering Other Positions

Over the course of the inquiry process, there will be times in which students disagree with each other and have to reach a resolution. If the environment of the classroom is one of respect, students will learn to work with others who have differing ideas. For a student like Austin who has never used inquiry, this experience will probably be new. Teachers have to ensure that students are provided opportunities to revise their own thoughts and ideas while considering differing viewpoints. This could be a simple activity such as reflecting on learning and sharing these ideas with others or a more detailed exercise involving an audience. Either way, this revision of ideas with collaboration will allow students to continue the dialogue and consider new or previous ideas as solutions to problems. As students participate in inquiry, they also learn to ask questions about what is considered valuable information that should be further considered (Banjeree, 2010). Often, this decision is not one that is made as individual – students must work together to decide what is valuable. Joseph Massaquoi points out that science education is "concerned with the sharing of science content and process within the community." This is a vital part of the scientific process and exemplifies the fact that "doing" science relies on others' ideas (2009, p. 64).

Conclusion

Successfully incorporating scientific inquiry into regular classroom practice is a daunting task for educators: it takes time, practice, and the revision of learning materials to refine lessons to truly allow students to participate in inquiry. There is no doubt, however, that it is time well spent. Students who truly understand science are those who learn using the skills required for inquiry. "Research indicates that learners benefit from opportunities to articulate their ideas to others, challenge each others' ideas, and, in doing so, reconstruct their ideas" (Roseberry et al. as cited in NRC, 2000, p. 119). For many students, the use of inquiry could change their entire outlook on science. This process helps students to make connections to the real world that they may not have seen before. Inquiry also helps students to develop problem-solving skills that prepare them to be informed citizens. While the intellectual skills that students learn from inquiry are important, the interpersonal skills that students develop may benefit students in much more dynamic and far-reaching ways. Students who are part of an inquiry community learn to interact with oth-

ers to develop ideas and understandings, so they must together create a learning community of thought, process, and understanding where communication and collaboration are vital. Inquiry encourages acceptance of others and their ideals along with a willingness to find ways to work together to create a deeper understanding of science. Throughout their lifetime, these skills will be invaluable tools as students enter into to the greater societal community.

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