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Recommended Citation

Richmond, J. R. (2017). Argumentation in the High School Science Classroom: Underutilized and Misunderstood. *Learning to Teach*, 6(1). Retrieved from <http://utdr.utoledo.edu/learningtoteach/vol6/iss1/11>

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Argumentation in the High School Science Classroom: Underutilized and Misunderstood

Jillian R. Richmond

Abstract: Argumentation is a crucial part of discourse in the scientific field, but is rarely found in the science classroom. This raises the questions of why teachers are not using argumentation, as well as what benefits argumentation provides in the science classroom. Argumentation is not widely used in the science education field due to lack of teacher knowledge about integration techniques and teachers' fear of unruly class discussions. However, research shows that students benefit in many ways from argumentation based learning by allowing students to work through real world problems to develop higher level thinking skills. This paper discusses the importance of argumentation in science learning, ways to increase argumentation in the science education field, and specific techniques of argumentation that can be implemented in the science classroom.

Introduction

Jack plops down on his couch after a long day of work and turns on the news. The newscasters are debating a new law that would require the labelling of GMOs. One newscaster is practically yelling that GMOs cause cancer, while the other stands firm in their belief that GMOs are harmless. Jack thinks back to his high school biology class, and remembers that GMO stands for Genetically Modified Organism. He can't remember much past the definition, so he pulls out his laptop and starts to Google. "GMOs Will be the Death of Us All" one article blares. "10 Reasons Why GMOs are Crucial for the Future" declares another. As he scrolls through the articles, he thinks to himself, "How can anyone know which side to believe when there is so much information out there?" As Jack continues to scroll, he becomes frustrated and feels his education has failed him. He knows that mitochondria are the powerhouse of the cell and can list off Newton's Laws of Motion, but he has no idea what his opinion on GMOs should be or how to start developing one. He thinks of the science issues he sees debated everywhere from his television to Twitter: climate change, oil pipelines, renewable energy, water quality, ecosystem degradation, fertilizer use, and a variety of others. He knows that these topics were discussed in the science classroom, but he has no idea what information to believe in the vast abyss that is the internet. He closes his computer and changes the channel, and decides that the rest of the voting public can figure out what the right option is for this GMO law without him.

Where Science and Politics Intersect

Jack is not alone in his inability to discern which sources of information are scientifically valid and which are not. In the information age we live in, many people don't know what to believe, while others simply trust the first source they read. In the current political climate, there are a variety of scientific issues on the ballots that require citizens to do their own research and form their own opinions. As science educators, it is our duty to make sure that students who come into our classrooms not only learn the science content, but also learn how to find scientifically accurate information, process that information, and form their own opinions. Luckily for science teachers everywhere, argumentation can be used in the classroom not only to teach science content, but also to help students develop higher level thinking skills and form opinions based on scientific evidence, rather than depending on the first news source they see.

Scientific Discourse and Argumentation

Scientific discourse is how scientists interact with each other and exchange information. In the science classroom, it is important that students learn different forms of scientific discourse so they can interact with each other and with the scientific content. Argumentation is a form of scientific discourse that is only occasionally used in the science classroom, but is widely used in the field of

science. The basis of scientific argumentation is reasoning scientifically based on information in order to create a position, to present a new idea, or to refute an existing position or idea. Argumentation is important in education because it allows students to work through scientific knowledge by using higher order thinking skills, such as the synthesis and evaluation levels in Blooms Taxonomy. In fact, using argumentation as an educational tool is not a new idea and was used for teaching as far back as Plato and Aristotle (Eduran, 2006).

How is Argumentation Used In Science?

Scientists in the field use argumentation often. Initially, when scientists start out with an idea for an experiment or a procedure for how to conduct an experiment, it is generally critiqued through argumentation-based processes. Scientists must talk to their peers to determine if their hypotheses and experiments are valid and relevant to the field and to decide whether they make sense from a scientific perspective. Once a scientist has finished conducting their experiment, they typically attempt to publish the findings. These scientists generally write scholarly articles, which must be critiqued by other scientists many times in an argumentation-based process before the articles are published. Similarly, Master's and PhD students in the sciences generally write a thesis or dissertation which must be critiqued and approved by a panel of scientists and professors. These students sit in with a panel of experts and defend their thesis by answering critical questions. Since argumentation is an integral part of the scientific process, most science educators think that it should be an integral part of the science classroom.

Why Is Argumentation Important in the Classroom?

To truly understand science, students need to know how evidence is used in science to construct explanations, and how arguments form links between data and theories that science has already constructed. Thus, in their article "Establishing the Norms of Scientific Argumentation in Classrooms" Newton and Osborne (2000), argued that current science classrooms are organized around reading and experimentation when they should revolve around socially-constructed science. The idea of integrating more argumentation into the science classroom has been around for a long time, yet modern day science classrooms generally offer little to no argumentation in their curriculum. Newton and Osborne make the case that factual recall and memorization is not the basis of science, and that these skills are not very useful in the scientific community. The article claims that although modern day science classrooms teach you the "What" (meaning what a scientific term is), they don't cover the most important bases. They argue that argumentation in the classroom would help teach students the "How's" and the "Whys" as well. Argumentation can help teach students how a phenomenon works, how it relates to other phenomena, and why it works the way it does. If a student only learns one "how," "what," or "why," they are missing the big picture that can be mastered through argumentation. For example, turning back to Jack and the political issue of GMOs, it is clear that Jack had only learned what a GMO was, but had missed out on learning the "Hows" and "Whys" of GMOS. If Jack had been taught through multifaceted argumentation, he would likely have had an idea of what GMOs are, how they work, and why they are pertinent to society, which would allow him to have or create a logical and scientifically-based opinion on the issue.

Jack's case illustrates Newton and Osborne's (2000) final points about why argumentation should be used in the science classroom. First, there are many issues that the public has control over such as those related to air quality, water quality, the destruction of ecosystems, GMOs, and the use fertilizers in agriculture. These issues are complicated and there is rarely a simple "right" or "wrong" side. Due to the complexity of these scientific issues, it is important that the public be able to evaluate them and to be informed on what they are voting for or against. As seen in Jack's case, the lack of a deeper understanding of the issue of GMOS, combined with a deficiency in the skills needed to form an opinion, led him to back away from current political issues. Secondly, it is important that the public understand what science really is and what scientists do. A large part of the population doesn't understand how the scientific community works or why argumentation is integral to the scientific process. Newton and Osborne claim that if we want a scientifically educated population, we must teach students the ability to know how to become scientifically educated on a topic.

Research shows that teachers can be taught to use argumentation in the science classroom. Demiriglu and Ucar (2012) performed a study that shows the positive effects of argumentation in the science classroom. This study evaluated the effects of Argument Driven Inquiry (ADI) laboratory activities with pre-service teachers. An ADI lab is essentially a science lab that allows experimenters to decide how to run their experiments, for example deciding what steps to take, by using argumentation with the group. In their study they worked with 63 pre-service teachers, and dividing them into a control group which completed a standard lab with a predetermined procedure, and an intervention group that completed an ADI lab. The group that completed the ADI lab controlled how they experimented and used argumentation to figure out the best way to do so. Afterwards, the control group and the test group took a test that was identical to the pretest they had taken before they did the experiment. Although there were no differences in the content scores between the two groups, the positivity scores on the experiment from the test group were much better than the control group, indicating that those who were able to develop and test their own experiments felt much more positively about the experience, and about science than those who had performed the pre-made experiment. For this reason Demiriglu and Ucar believe that those in the test group would be likely to use ADI in their own classrooms, leading to similarly increased engagement on the part of their students.

Why Is Argumentation Underutilized?

Many scholars argue that the reason argumentation is not commonly used in the science classroom is the lack of pre-service teacher instruction on how to implement argumentation-based teaching in the classroom (Duschl, 2002). As Demiriglu and Ucar (2002) showed when teachers learn how to use argumentation as pre-service teachers, they are more likely to use argumentation in their own classrooms. Generally though, teachers struggle with implementing classroom procedures that they have not learned how to use or with which they have not yet gained experience in their own education. As with other education techniques, practice makes perfect, and when teachers start to use argumentative practices in the classroom, they only get better at doing so.

How to Use Argumentation in the High School Science Classroom

A lot of research supports the idea that argumentation is important to the classroom and to the scientific community, but discerning what argumentation techniques are best for use in the classroom is a topic still in its infancy. Although argumentation has been used historically in science and in the classroom, studies of its implementation have fallen to the wayside.

The most common argumentation technique used in the classroom is debate. This involves having students pick sides or assigning students sides of a particular issue, and having them engage in a structured debate. In my experience, many teachers feel uncomfortable with the idea of debates in their classrooms for two reasons: the time commitment and the lack of control. It is important for teachers to note that debates can last for as little as one class period, and that when there are structured debates in the classroom, they can still be a moderator who controls the flow of the debate without taking away students' freedom. Jack's situation may have been very different not only if he would have understood GMOs in a multifaceted way, but more importantly if he had the skills to develop an opinion by doing his own scientifically accurate research. When students enact argumentation-based debates in the classroom, it allows them to examine an issue from many different angles. Finally, through debate, students learn how to research an issue and form an opinion using higher-level thinking skills as opposed to just reading and regurgitating information.

There are many other ways to use argumentation in the classroom. One argumentation technique is facilitating students as they constructively critique each other's work. This can be done by allowing students to look at each other's experiments, projects, or papers and directing them to use constructive criticism techniques to help improve their work. Another method is to have guided discussions in class, which can be done by asking questions with no definitive answer and allowing students to discuss possible answers. Such guided discussion can take place in a whole class setting or in small groups in which students discuss among themselves. Another common argumentation technique that can be used in the classroom is assigning argumentative papers, where students either pick or are assigned a certain side of a scientific issue and are expected to validate it through writing.

Argumentation can also be brought into the classroom by allowing students to create their own experiments for various science topics. Another way teachers can use argumentation is by having students make predictions that strengthen their explanations. This is done by having students predict the results of an experiment by using their previous logic from another experiment or scientific explanation. Teachers can also ask students to reconcile competing explanations, meaning that students must find a common understanding or explanation between two results or findings that may seem to contradict each other. Lastly, teachers can have students build a consensus from multiple contributions. This requires students to compare and contrast different sources to form a larger consensus of data from multiple sources. If it involves students looking at an issue from multiple view points and taking a stance, it is argumentation.

Many science classrooms follow a model in which teachers relay facts or truths to students, as opposed to using argumentation to explain a topic. Osborne (2010) explains the difference:

An argument, in contrast, is an attempt to establish truth and commonly consists of a claim that may be supported by either data, warrants (that relate the data to the claim), backings (the premises of the warrant), or qualifiers (the limits of the claim). (p. 464)

Argumentation can also be used with students to teach them about different topics, and allow them to see topics as multidimensional, as opposed to being given only one viewpoint on a topic and being expected to memorize facts. In Jack's case, his teacher had probably focused on relaying facts about GMOs, such as the definition of GMOs and examples of them, instead of diving into the arguments made by pro- and anti-GMO proponents and allowing students to formulate their own opinions.

Eduran (2006) conducted a study on argumentation and his research revealed two important things: first, that teachers can learn how to integrate argumentation into the classroom, and second, that students' argumentation skills improve with practice. One of the high school chemistry teachers involved in the study conducted an argumentation lesson on the periodic table. She had the students use argumentation to arrange a periodic table and determine to what class (Metals, Non-Metals, Metalloids) various elements belonged. Students helped to critique other students' evidence arguing whether a particular element was a metal or non-metal. Another high school chemistry teacher who participated in the study, taught a similar lesson, but only posed a single question: Was mercury a metal or non-metal? Students researched both sides of the issue and used argumentation to come up with a final answer. This research shows that something as simple as determination of what class an element belongs to can be taught using argumentation. When students are told that certain elements belong to certain classes, and given the reasons why, there is a chance they will remember what they have been taught. However, when students must use higher-level thinking skills to discern for themselves what class an element belongs to, it is much more likely they will internalize that information. Knowing that students improve the more they practice makes argumentation even more worthwhile in classrooms. If Jack had practiced argumentation on other science classroom topics that were not GMO related, he might have built the higher-level thinking skills required to conduct his own research and make scientifically informed decisions long after he left the classroom.

Conclusion

When students exit classrooms and step into the real world, they will be faced with many decisions. These choices range from which career path to go down to which way to vote on various issues. It is a school's responsibility to make sure that students are educated enough to make good choices without the guidance of a teacher, counselor, or parent. Schools and teachers can prepare a generation of students who are socio-scientifically educated, and who are able to research various issues without just regurgitating what they see on TV or online. In a society which is inundated with such controversial issues as climate change, GMOs, and the use of renewable energy, students should be able to use argumentation to evaluate an issue from multiple sides and to form an educated opinion.

Luckily for teachers, students typically get better and better each time they practice argumentation (Eduran, 2006). Because of this, students at any age can learn how to be more argumentative in their thinking. The science education community needs to put more research into what types of classroom environments best nurture argumentation if they want teachers to use more specific practices in their classrooms. The pre-service science education community needs to integrate more argumentation techniques into their curriculum to help teachers to learn to help

students. Duschl and Osborne (2002) claim that “[l]earning to argue is learning to think,” and by that logic, teachers have an obligation to teach students how to argue.

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