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Socio-Scientific Argumentation as a Driver for Science Learning

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Abstract
Socio-scientific instruction is a decades-old framework for teaching; however teachers still struggle with meaningful classroom implementation. If the goal of education is to create critical thinkers who can logical examine scientific arguments then we must provide students with opportunities to engage in argument. For this reason, we recommend using SSI as a driver for classroom science learning. In SSI, the outcome of the argument is not as critical as the process of argumentation, enveloping the nature of science throughout; allowing students to make and support claims, counter-argue, discuss, and respond critically to others, all while learning how science content impacts their world. Using three simple phases of SSI implementation: prior knowledge, activation, and evidence to enhance student-centered exploration in science may improve teacher willingness to employ SSI strategies in their classrooms.

When asked what their primary goal is for their students, most teachers will say they want students to be problem solvers and critical thinkers. Simonneaux agrees, stating that, "schools in a democratic society [should] train citizens capable of debating controversial scientific issues" [11]. Therefore, students must be well rounded, able to formulate arguments based on evidence, and express those arguments articulately. However, traditional standards do little by way of incorporating activities that allow students the opportunity to develop these skills. In response, socio-scientific argumentation offers students opportunities to safely argue topics, engage in research, and explore the connections between classroom content and larger world [1][2][4][5][6][7][9][15][17].

Integrating socio-scientific issues (SSI) into the science classroom is not a new concept. However, its adoption has waned based on teacher comfort level, standards-based teaching, and standardized testing for accountability [4]. Numerous studies indicate that teachers are not comfortable with using SSI due to the moral, ethical, and cultural eggshells many of these concepts bring with them [1][2][8]. Essentially, teachers are fearful of impact on class management, parental reaction, administrative pressures, and feelings of inadequacy in content areas. The focus of education in the modern era has shifted from teacher-centered to student-centered, yet many fail to take the steps to allow students to become the drivers of content. By allowing students to teach each other through debate and problem solution, they are more open to seeing the connections between their world and the content.

Students interpret their experiences through their worldview-their way of thinking and believing based on experiences, friends, and family-and are not fully capable of separating opinion and evidence in science [3] [9][16]. Furthermore, they are less likely to appreciate world societal problems not related to their time and place in the world [1][4][15][16]. To countermand these roadblocks to engagement, we argue that SSI, implemented at each grade level can combine relevant curriculum and thinking skills. These investigations encourage students to step outside of their worldview; listening to all sides of an argument, evaluating evidence, and developing personal position based on these interpretations [11]. SSI is a pedagogical approach that can be easily implemented regardless of student age, maturity, and course content. SSI is a means of allowing students to see the science behind the issues, learn there is often not one right answer, appreciate counter argument, and understand science is more than a collection of facts and laws [1][2][8]. These traits tie naturally to curiosity of students across grade bands and serve to help them explore and understand their world outside of the science class as much as within.

The goal of SSI is to challenge students to explore where data comes from and how it frames scientific knowledge[1][2][5][15][16]. This allows and encourages students to think for themselves and construct valid arguments using scientific, and other, evidence to justify their positions, beliefs, and opinions [6][7][9][15]. Therefore it is the process of argumentation, and not the topic itself, that is of focus and import. Our modified framework for SSI is based the potential for teachers to advance knowledge and students to acquire knowledge through content that supports the argumentation of socio-scientific issues.

It is important that while SSI is placed as a driver, the framework is cyclical--as new information arrives to support or contradict an opinion, the cycle can restart or shift at many different points. It is not a single progression of information but rather a process of ongoing evaluation and integration, challenging students to investigate claims by seeking data and information on their own. Throughout this process, students learn to develop and use argumentation, science content, informal reasoning, decision-making, and reasoning skills. They explore first-hand how and where science is embedded within their lives and the world around them.

The process of argumentation is a skill-set that is honed with practice over time, rather than a linear process easily learned in a day of traditional professional development [18]. Teachers must devote time to their own learning, be willing to practice, scaffold their learning, and start small [3].

Explicit training surrounding scientific argumentation (part of the nature and process of science) or navigating controversial issues are not the norm in teacher education [10]. In order to do this, the process of argumentation must first be seen not as a lesson to be taught but rather a skill to be refined over time. Teachers and students alike must be continually challenged to examine the difference between evidence, opinion, and fact within and across comfort levels. This requires that teachers be expert facilitators of argumentation rather than purveyors of facts [18][7]. Teachers must be confident in their own understanding of the Nature of Science (NOS) and pedagogical approaches that integrate NOS across standards, content areas, and disciplines. The facilitative role of the teacher surrounds helping students understand why "inadequate [arguments] are inadequate", empowering them to reach levels where they are able to evaluate and test arguments independently [3]. To reach mastery, teachers must continually guide student inquiry, demand evidence to support claims, clearly articulate the basis for evaluation of arguments, and encourage the use of reflection based on argument and evidence [3].

Nature of Science understanding is crucial to the development a scientifically literate society and should be modeled for students, and practiced, prior to the implementation of SSI [7]. While it is acknowledged that not all students will study science, all students can learn the value of evidence based arguments to support views. According to Jimenez-Aleixandre classroom environments that promote argumentation place expectations on students to 1) produce justified answers, 2) select competing explanations of phenomena, 3) use evidence to support claims, 4) to evaluate arguments, 5) use the language of science in writing and argument, 6) convince others of their view, and 7) be critical consumers of others findings [3]. In essence, students become evaluators of research, consumers of knowledge, and developers of arguments based on evidence through continued practice of SSI.

Most argumentation in science classrooms involves abstract scientific data and/or prescribed experiments that have little direct impact on student lives. While these activities can serve as gateways for teachers to explore the process of argumentation, they hold little extraneous value for students. However, having students examine evidence, discuss results, draw evidence-supported conclusions, and receive feedback from others immerses them in whole process of critical evaluation. This is in high contrast to simply dropping students into the middle of a problem with no modeling or process for understanding; a practice commonly undertaken in laboratory and data exercises that seldom reaches the depth of knowledge needed for lasting understandings.

Although the literature acknowledges teacher support of SSI as a powerful tool for classroom learning [10][11][13][15][18], there are still disparities in practice . Reasons for this discrepancy are many--high stakes testing in the United States, parental concern over teaching controversies, and lack of teacher comfort. However, SSI can be implemented in a more consistent and routine manner through the use of scaffolding student and teacher learning. While it stands to reason teachers who receive training on argumentation are more likely to implement in their classrooms, formal training is not necessary for teachers to begin the process. It is recommended that teachers steer away from strongly controversial topics (global warming, evolution, GMO's, etc.) initially until they grow more comfortable with the process of argumentation. However, as teacher comfort level with facilitating argument grows, more advanced topics can be included and the entry order of phases adjusted.

Below is our recommended action phase (Figure 1) for implementing SSI into any course, each to be based on the standards for that grade level. Throughout each phase, the NOS and argumentation processes are continually reinforced. In addition, the phases are cyclical, building continually as arguments shift, and not limited by time.

Phase	Activity
Prior Knowledge	Students are introduced to a "control" content topic to learn about NOS and argumentation.
Activation	SSI topic introduced based on grade level and content.
Evidence	Students practice argument based on content and experiment in the class (scientific argumentation).

Figure 1: Recommended Implementation Phase

Figure 2 shows a recommendation for phase implementation in a high school biology class.

Phase	Activity
Prior Knowledge	Can scientific theories be changed?
Activation	Nature vs. Nurture – which has a greater impact on development?
Evidence	Genes, heredity, evolution

Figure 2: Example High School Biology Plan

Utilizing SSI to drive science learning does not have to be a daunting task for teachers. It simply requires flexibility and willingness to rethink pedagogical approach. This requires encouragement, support, and empowerment for teachers as they integrate SSI in their classrooms. With the primary goal of education being to develop critical thinkers, educators must be willing to become critical thinkers themselves, modeling and guiding their students. SSI aligns with this goal by empowering teachers to engage students, explore socially-relevant issues, support their claims with evidence, and think critically about controversial issues. These three simple phases engaging prior knowledge, activating discussion, and evaluating evidence enhance student-centered exploration in science and empower teachers to let go of the reins, allowing students to develop their foundations and futures.

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