Developing case studies in teacher education: Spotlighting socioscientific issues

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Abstract

Despite the growing corpus of research on socioscientific issues (SSI) in science education, the relevant implications for science teacher education remain relatively unexplored. There is a need for preservice and inservice programs that challenge teachers' discomfort and suggest means for teaching controversial issues. In order to better inform these efforts, it is necessary to learn more about how preservice teachers use science curriculum materials dealing with SSI in science learning environments. One avenue for exploring SSI with teacher candidates (TCs) is through case studies. Case studies have had extensive usage in numerous disciplines; in science education case studies can take into consideration many different facets of science including epistemology, scientific content, and the nature of science. With the goal of gaining a better understanding of how to support TCs in fostering their future students' understanding of SSI, this research study was conducted while TCs were supported by their instructor in the development of case studies about SSI in a secondary science methods course. This paper outlines the processes involved in preparing and supporting TCs while they assumed dual roles – curriculum developers *and* co-constructors of knowledge – as they developed their case studies. Additionally, it provides a structure for developing case studies and highlights an example of a case study focusing on genetically modified salmon. Further, this assignment provides a useful framework for science teacher educators wishing to create appropriate SSI assignments for TCs in science education.

Introduction

A major goal of K-12 science education reforms worldwide includes the development of more scientifically literate students (American Association for the Advancement of Science, 1986; Australian Education Council, 1994; Council of Ministers of Education Canada, 1997). Traditionally the focus in science education has been on teaching and learning disciplinary knowledge. Conventional science teaching includes ''dealing with established and secure knowledge, while contested knowledge, multiple solutions, controversy and ethics have been excluded'' (Hodson, 2003). Many teachers fear that extensive coverage of socioscientific issues devalues the curriculum, alienates traditional science students, and jeopardizes their own status as gatekeepers of scientific knowledge (Hughes, 2000). In Ontario Canada, revised science and technology curricula for grades 1-10 require students to analyze socioscientific issues (SSI) through curriculum expectations in which they "relate science and technology to society and the environment" (STSE expectations) (Ontario Ministry of

Education, 2007, 2008). STSE education proponents advocate for literacy grounded in the context of ethical, individual, and social responsibility (Aikenhead, 1994; Kumar & Chubin, 2000; Pedretti & Nazir, 2011). Many teachers avoid the integration of SSI issues (Forbes & Davis, 2008; Zeidler, Sadler, Applebaum, Callahan, & Amiri, 2005) into the science classroom because they possess limited knowledge and skills to deal with complex issues, lack teaching strategies for dealing with these issues, and tend to place more worth in teaching the value-free concepts and skills of science than messy SSI concerns (Aikenhead, 2007; Lee & Witz, 2009).

Gray and Bryce (2006) concede that this new focus on complex, value-laden science requires a careful consideration of the professional updating of teachers' knowledge and skills. One way to address the professional updating of teachers' knowledge and skills is supporting them in learning to effectively use curriculum materials. Forbes and Davis (2008) suggest that, with support, novice teachers can learn to make effective adaptive decisions regarding existing curriculum materials. Teachers' work with science curricula can be supported through the development of educative curriculum materials (Davis & Krajcik, 2005), or those that are designed to promote teacher learning as well as student learning.

Science teacher educators also play a crucial role in helping preservice teachers learn to both effectively critique curriculum materials (Davis, 2006) and make decisions upon which their local adaptation of existing science curriculum materials is founded, especially with respect to SSI. Moreover, teacher education programs should promote relevant reading materials, foster discussions of science education goals, encourage collaboration in writing learning materials, and practice issue-based teaching (Tal & Kedmi, 2006). One avenue for exploring SSI with teacher candidates (TCs) is through the development of case studies that encompass the aforementioned objectives.

Case studies

Case studies have had extensive usage in numerous disciplines such as business, education, law, medicine, and e-learning (Choi & Lee, 2008) and have been widely used as a teaching tool in teacher education (Bliss & Mazur, 1996; Herreid 2006; Shulman, 1992) to help prospective teachers gain a deeper understanding of educational theories and principles and learn how to apply these theories to situations they may face in the classroom. Shulman (1992) outlines five seminal uses for case studies in the preservice curriculum: 1) to teach principles or concepts of a theoretical nature, 2) provide precedents for practice, 3) convey moral or ethical principles, 4) teach strategies, disposition, and habits of mind, and 5) provide visions or images of the possible. Moreover, case studies in science education can be used to help TCs consider many different facets of science including the general aspects of science, epistemology, scientific content, and the nature of science. In addition, case studies stress the active role of the learner and exemplify a narrative approach focusing on a storyline along a central idea (Höttecke & Riess, 2009). In order for students to develop scientific literacy that is founded on argumentation involving controversial issues, students need to adopt a more realistic view of science and its potential for resolving conflicts than is currently common (Evagorou et al., 2014). In addition, students must practice different approaches in class that encourages thinking and enables discussion of problems that would not necessarily have solutions, and even if they do, these solutions are quite often not within the domain of science.

Despite the growing corpus of research on SSI in science education, the teacher's many roles, as well as relevant implications for science teacher education remain relatively unexplored (Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006). There is a need for preservice and inservice programs that challenge teachers' discomfort and suggest means for teaching controversial issues. In order to better inform these efforts, it is necessary to learn more about how preservice teachers use science curriculum materials dealing with SSI in science learning environments. This paper explores TCs' development of learning materials in the form of case studies aimed at addressing SSI. Through the development of case studies, we explored TCs' knowledge of effective instruction and assessment practices that address STSE expectations in the Ontario science curriculum.

Developing case studies in teacher education

Context

The case study assignment was implemented in a secondary science/biology methods course in a faculty of education at a Canadian university. Forty TCs (9 male; 31 female) were enrolled in the course which consisted of twelve 3-hour seminars, with four seminars (seminar 5, 6, 8, and 9) dedicated to the development of SSI-based case studies as outlined below. These seminars were over the duration of 6 weeks, interspersed with other topics on secondary science methods. The instructor, one of the authors, developed the case study assignment based on a writer's workshop (DeCoito & Peterson, 2010) that was implemented previously in a science methods course.

The first of three goals of the *Ontario Curriculum, Grades 11 and 12 Science* (2008) program is to relate science to technology, society, and the environment. This is considered "an important component of every course in the science program and students are encouraged to apply their understanding of science to real-world situations in these areas and to develop knowledge, skills, and attitudes that they will take with them beyond the science classroom" (p. 10). Thus, the instructor was committed to providing opportunities for TCs to familiarize themselves with STSE frameworks. Furthermore, resources focusing on STSE education in practice were scarce given that the first goal outlined above was moved to the forefront in the revised science curriculum. Hence, this was the impetus, and an opportune time, to design an assignment that would be inclusive of the tenets of STSE education and SSI, as well as engage TCs in firsthand experiences with developing curriculum resources. The instructor was keenly aware that the assignment would have to be structured in a manner that would provide TCs with opportunities to reflect on and revise their case studies based on instructor feedback. Thus, effective implementation of the case study assignment would require a time commitment from the instructor such that all steps, including mentoring and conferencing with TCs and supporting them through the various processes including research and writing, would have to be carefully orchestrated in order for students to experience success in the various roles.

For this assignment, TCs assumed dual roles – curriculum developers and co-constructors of knowledge – as they designed their case study. In groups of four, TCs were required to develop a case study focusing on a SSI. Once they had selected their topic, each member of the group adopted a stakeholder role, depending on their particular topic. For example, if the topic they chose was climate change, stakeholders could potentially include environmentalists, civilians, politicians, scientists, and so on. In the various roles each member was required to complete a KWL graphic organizer, and using the Cornell Note-Taking© framework, research the topic from their stakeholders' perspective. Each TC in the group also completed a consequence map based on their stakeholder's perspective. The goal of the assignment was for TCs to experience the process of developing and completing a case study as a way to inform them about the importance of STSE and SSI, which they could then, in turn, implement with secondary science students in their future practices. This paper showcases an example of one representation, focused on genetically modified organisms (GMOs).

Supporting Students' Development of Educative Materials in a Science Curriculum Course

Seminar #5: Introducing and modeling SSI-based cases

This seminar acquainted TCs with STSE education, SSI, and case studies through assigned readings and a presentation on STSE education which highlighted SSI issues, including genetic engineering, climate change, ethics, and designer babies. Thereafter in groups, TCs completed an activity, Analyzing Case Studies, which introduced them to 4 different cases dealing with the impact of vehicles on the environment; managing forest and forest fires; cleaning up an oil spill; and genetic testing. The activity was developed by the instructor and the overarching goals were to: a) model various components of a case study, and b) analyze a case study. In this activity TCs were introduced to and completed various components involved in developing and analyzing case studies: KWL graphic organizers, Cornell Note-Taking© frameworks, consequence maps, and cost-benefit analysis. In groups, TCs were randomly assigned a case study, which they read and came to a consensus on the issue that was highlighted in the case study. Group members shared what they knew about the issue, negotiated appropriate stakeholder groups, such as automobile manufacturers, health care professionals, and environmentalists, and discussed different perspectives of each group. They then completed a consequence map for each stakeholder and a cost-benefit analysis for the case study. The consequence map is an appropriate graphic organizer for this activity as it provided an opportunity for TCs, while assuming specific stakeholder roles, to consider the potential long-term impact of their actions, including the interrelationships, cause and effect on the case study topic. Thereafter, in a class discussion each group discussed their case study, provided a rationale as to why they chose specific stakeholder groups, and explained their cost-benefit analysis and potential solutions. This activity modeled for TCs the processes that would be involved in the upcoming SSI case studies assignment, namely it provided insights into various SSI topics, modeled the components and procedures involved in case study development, and demonstrated how to conduct cost-benefit analysis and assessment of potential solutions and alternatives.

The Analyzing Case Studies activity fostered metacognitive strategies that span three distinct phases – planning, monitoring, and evaluating (Flavell, 1976; Thiede, Anderson, & Therriault, 2003). Specifically TCs were required to reflect on their own learning and identify areas of strength and need during the case study analysis. These tasks offered TCs the chance to set their own personal goals and advocate for their own learning in terms of what they learn, how they learn, what helps them learn, and how they can demonstrate their learning, and is reflective of activities that promote assessment as learning (Ontario Ministry of Education, 2010). The following questions guided TCs' reflections:

- What skills did you use to conduct the activity?
- What prior knowledge did you need or what research did you have to conduct in order to complete the activity?
- How would you describe your teacher role in this activity?
- Which type of thinking most influenced your opinion of the proposed course of action?
- Which type of thinking hindered progress the most?
- Which type of thinking do you think was most challenging?

After the activity, the class discussed some of the challenges and successes they faced in completing the various tasks. It was evident that TCs felt that a variety of skills were needed to complete the activity, including researching various stakeholders and amalgamating information, listening to stakeholders and critically assessing their viewpoint, as well as evaluating consequences in order to make informed decisions and/or propose potential solutions. There was consensus that the teacher's role should reflect that of a facilitator. The activity not only provided insights into various SSI topics and modeled the various components of case studies, it also required that TCs reflect on their own learning and identify areas of strength and need. This was instrumental as the reflections guided TCs' thinking and negotiations in subsequent seminars as they developed their case studies.

After this activity the class brainstormed some 'real life' issues that could be adapted and taught within a SSI framework. TCs formed groups, consulted curriculum documents, and selected an area of the curriculum to focus on for their case study.

Seminar #6: Conceptualizing case studies

TCs were introduced to the case study assignment (Appendix 1), including the different components as modeled in the case study analysis, and the assessment criteria. The instructor provided examples of KWL graphic organizers, Cornell Note-Taking© frameworks, consequence maps, and cost-benefit analysis from previous case study exemplars. The remainder of the seminar was dedicated to TCs researching their topic and consulting with the instructor about the assignment. Prior to the class, groups were encouraged to bring resources to class for researching the topic. Some TCs were challenged in terms of choosing a topic that was SSI based, with a focus that was appropriate for developing a case study. For example, one group chose to construct a case study around a hypothetical landmark case that would decide if extinct species, such as dinosaurs, should be cloned from ancient DNA found in fossils. This was problematic as group members found it difficult to focus the case study (i.e., from an ethics or biological viewpoint) and identify key stakeholders. As a group, the TCs revisited and refocused their topic from a biological viewpoint, with an ethical perspective embedded as opposed to being the main focus, before developing the learning goals and scenario for the case study.

Overall, during consultation with the instructor about potential topics, it was obvious that TCs' knowledge and understanding of SSI varied, with some students struggling to situate SSI in the framework of science teaching and learning. There was a general tendency to treat SSI as a special topic, distant from school science, with most TCs focusing on societal issues that can be 'solved' using science. One TC articulated conflicting views as he considered teaching about SSI in his future practice:

Science is hard facts and of course harder to get students to think about it in a different way. We put issues on the back burner, when you are explaining all these things, and you really want students to understand, it's hard to, also, at the same time deconstruct them and talk about how they are socially relevant … it's a challenge.

This is not surprising given the fact that despite explicit STSE expectations in Ontario's science curriculum documents, TCs have had limited exposure to STSE in high school. Hence, most of them were engaging with STSE and SSI for the first time. In order to ascertain that TCs were selecting topics that were SSI based and suitable for developing a case study, the instructor met with groups and probed the topic choice in terms of rationale and their vision for the case study. The seminar concluded with the instructor assisting groups in developing scenarios and formulating questions related to decision-making skills using consequence maps (Appendix 1, Section A-C).

Seminar #8 – Researching and developing case studies

This seminar was devoted to the instructor conferencing with TCs to support their research and development of the case studies including their writing, providing feedback on consequence map development, cost-benefit analysis, organizing and presenting their case studies, referencing, and so on. The instructor ensured that all groups had an opportunity to conference since this seminar was the first opportunity for TCs to discuss the various components prior to submitting their draft case study. One of the challenges encountered by TCs was summarizing the research based on the Cornell Note-Taking© framework, specifically in terms of including key ideas based on their original question(s). TCs' development of consequence maps also proved to be challenging as they experienced some difficulty assuming their stakeholder role, as well as envisioning how their role would affect various groups. Based on the draft case studies, it was evident that TCs were somewhat reluctant to consider multiple solutions having absolutely nothing to do with science, or perhaps no solution at all. At the end of the seminar, draft case studies were submitted to the instructor for feedback (e.g., stakeholders' perspectives represented on concept maps, Cornell Note-Taking© summaries, scenarios, and learning goals of case studies).

Seminar # 9 – Refining case studies

In the final seminar dedicated to the case studies assignment, draft case studies with accompanying feedback were provided and TCs met in groups with the instructor to address feedback. This seminar provided TCs with the opportunity to reconsider, if necessary, their viewpoints and potential solutions. The instructor proposed questions that prompted TCs to revisit the KWL graphic organizer and review the section focusing on "what I learned." TCs also explained how each of their consequence maps contributed to potential solutions. Thereafter, groups revised and resubmitted their cases at a later date. The case studies were then presented on the final day of the course.

Issues-Based Case Studies

Some of the cases developed by TCs included: *Sustainable Ecosystems, Three Gorges Dam, Climate in the Southern Hemisphere,* and *Genetically Modified Organisms,* to name a few. The exemplar presented in this paper on Genetically Modified Salmon is a particularly good example of a case study created by TCs as it illustrates the depth of student thinking and exemplifies 21st century learning skills, including collaboration and critical thinking (DeCoito, in press). As mentioned previously, TCs assumed dual roles – curriculum developer and co-constructors of knowledge – which required them to develop, as well as research and complete the various components of a case study. Overall, the case study exemplar includes the following: (a) learning goals for the particular case; (b) a scenario to introduce the case study; (c) stakeholders involved in the SSI; (d) the student task (Figure 1); (e) for one stakeholder: KWL graphic organizer (Figure 2), Cornell Note-Taking© framework (Figure 3 – without a summary of research on the topic), consequence map (Figure 4); and (f) the presentation format for the case study (Figure 5).

Figure 1 (Click on image to enlarge). Case study: learning goals, scenario, stakeholders, and student task.

The Case Study: Genetically Modified Salmon

Learning goals

- Analyse some of the social, ethical and legal issues associated with genetic research and biotechnology.
- Analyse, on the basis of research, some of the ethical and legal implications of biotechnology (e.g., bioengineering of animal species especially those intended for human consumption; the cultivation of transgenic crops; the patenting of life forms; cloning).
- Analyse on the basis of research, some key aspects of Canadian regulations pertaining to biotechnology and compare them to regulations from another jurisdiction

The Scenario: Genetically Modified Salmon

Recently, genetically modified salmon has been created and is being assessed in order to be sold in local supermarkets. Genetic modification of foods has been used for a long time; the first genetically modified food sold on the market was the tomato. If approved, salmon would be the first transgenic animal to be sold to the public. Aquadvantage is the company responsible for using biotechnology to create this new breed of salmon. Genetically modified (GM) salmon has genes taken from both the Chinook salmon and pout fish; this gives the salmon the ability to be farmed year round. Additionally, the salmon is given growth hormone to stimulate rapid growth. When compared to natural salmon, GM salmon can grow up to one kilogram in a year, whereas natural salmon usually weigh to two to three hundred grams in that same amount of time. One implication is that it takes a shorter time for GM salmon to reach market weight, therefore giving the ability to produce more salmon in a shorter amount of time. It is estimated that it takes GM salmon one year to reach market weight, while it takes approximately three years for natural salmon to do the same.

Stakeholders in Genetically Modified Salmon Issue

1. Canadian and American Government
2. Food and Drug Administration
3. Consumers/ General Public
4. Scientists that are conducting research
5. Atlantic Salmon Federation
6. Aquadvantage

Student Task

Students will be placed in groups and will be responsible for developing arguments or concerns for a stakeholder. All groups will come together to debate the issue of GM salmon from the point of view of their stakeholder. It will be their responsibility to conduct further research about the topic at hand. They must identify what the potential consequences are for allowing the sale of GM salmon. Here are some questions that will guide their research:

- What parties are involved with this issue? (e.g., government, scientists, regulating bodies, etc.). Identify the concerns of each party.
- What are the claims that the company have created for the GM salmon?
- What are the effects of eating GM foods, more specifically, GM salmon?
- What are the various environmental, social, economic, ethical, and safety impacts of GM salmon?
- Who opposes the sale of genetically modified salmon and why?
- What are the associated advantages and disadvantages of genetically modified salmon?

Figure 2 (Click on image to enlarge). KWL graphic organizer for GM salmon.

KWL Chart for GM Salmon - Stakeholder: Aquadvantage

What do I already know about genetically modified foods?

1. Genetically modified foods range from foods that were specially bred for certain traits to foods that were genetically altered at the DNA level.
2. Genetically modified foods are not labelled in the grocery store. As a result, you do not know if you are consuming genetically modified foods or not.
3. Recently, salmon has been genetically modified to grow at a much faster rate compared to traditional salmon. They are in the process of attempting to approve the sale of this salmon at local neighbourhood stores.
4. The first genetically modified crop was the tomato.
5. Genetically modified foods have been heavily criticized by the public, although GM foods have been sold in the supermarkets for many years.
6. There is currently no GM animal that is sold in supermarkets.
7. GM salmon could be very profitable as it can be mass produced fairly easily.

What I want to know about genetically modified foods.

1. Who is responsible for approving the sale of GM foods to the public, and what do they assess?
2. What is the price difference between the genetically modified salmon and wild salmon?
3. What are the benefits, if any, of genetically modified salmon?
4. What is the overall cost of producing one GM salmon?
5. What are the consumers' opinions about consuming genetically modified foods?
6. Does the GM salmon have any negative effects on the environment? If so, what are they?
7. Is there a regulating body that is in charge of testing GM salmon?

What I learned about genetically modified salmon?

1. The FDA has found that genetically modified salmon has no significant nutritional differences when compared to traditional salmon.
2. The DNA of Chinook salmon and the pout fish …

Figure 3 (Click on image to enlarge). Cornell Note-Taking© Framework for stakeholder.

The Cornell Note-Taking Framework - Stakeholder: Aquadvantage

Source: http://abcnews.go.com/Health/Wellness/genetically-modified-salmon-fda-review/story?id=11645616

Questions	Notes
○ How are genetically modified foods assessed?	○ Transgenic animals have been created but not for consumption purposes.
○ What are the possible environmental effects of genetically modified salmon?	○ Aquadvantage is the company that developed GM salmon.
○ Who is responsible for approving the sale of genetically modified foods?	○ The Atlantic Salmon Federation, an organization that represents salmon fishers, opposes the idea of selling GM salmon.
○ What do environmentalists think about the issue?	○ Health Canada requires prior notification of the sale of GM plants but currently there is nothing in place for animals.
○ How are salmon fishers/farmers reacting to this new technology?	○ GM salmon is environmentally friendly as it produces less waste than regular salmon.
○ What process was involved in order to genetically modify the salmon?	

Figure 4 (Click on image to enlarge). Stakeholder consequence map.

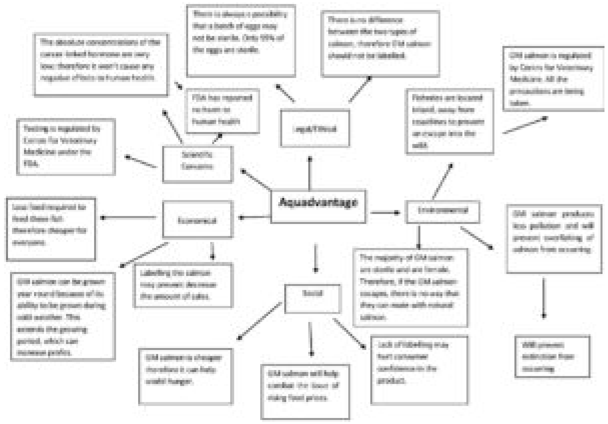
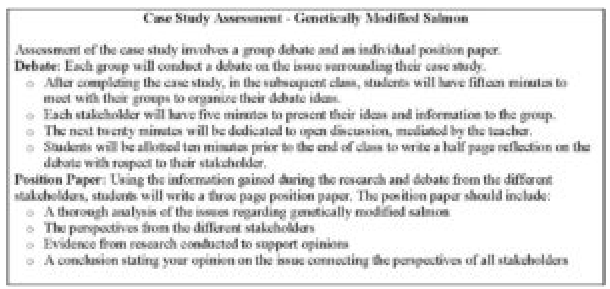


Figure 5 (Click on image to enlarge). Case study presentation and assessment.



Case Study Assessment - Genetically Modified Salmon

Assessment of the case study involves a group debate and an individual position paper.
Debate: Each group will conduct a debate on the issue surrounding their case study.

- After completing the case study, in the subsequent class, students will have fifteen minutes to meet with their groups to organize their debate ideas.
- Each stakeholder will have five minutes to present their ideas and information to the group.
- The next twenty minutes will be dedicated to open discussion, mediated by the teacher.
- Students will be allotted ten minutes prior to the end of class to write a half page reflection on the debate with respect to their stakeholder.

Position Paper: Using the information gained during the research and debate from the different stakeholders, students will write a three page position paper. The position paper should include:

- A thorough analysis of the issues regarding genetically modified salmon
- The perspectives from the different stakeholders
- Evidence from research conducted to support opinions
- A conclusion stating your opinion on the issue connecting the perspectives of all stakeholders

Conclusion

In reflecting on TCs' engagement during the development of case studies, it is evident that TCs tackled the case study assignment with much enthusiasm. However, it was apparent that many of the topics they chose were too broad in scope. Hence, their biggest challenge was selecting a scenario that they could develop a case study around. Despite incorporating the elements of a good case study, along with key criteria including scenario development, the students struggled with elements of writing in particular, especially amalgamating summaries resulting from their research, along with consequence mapping, and identifying key stakeholders. As a result, TCs often had to review their peers' consequence maps to ensure that the particular stakeholders were being represented in the appropriate manner.

In the end, TCs achieved much success in the development of case studies addressing SSI and promoted not only student learning, but also teacher learning. Indeed, TCs felt that their content learning was enhanced because they had to review and reshape their knowledge in order to develop the various elements of a good case study. In addition, they credited the support and mentorship they received from their instructor throughout the process in terms of posing challenging and thought provoking queries around topic choices, scaffolding the writing process, modeling good practice, and providing guidance and feedback on their drafts as key aspects of their success in developing the cases.

Achieving broadened conceptions of scientific literacy will require science teacher educators to determine how best to inform preservice and inservice teachers about the importance of SSI as a key aspect of science teaching and learning, and how to implement strategies for teaching about SSI in the classroom. The promotion of scientific literacy requires curricular attention to the moral and ethical implications of SSI (Zeidler & Sadler, 2007). Students should be provided with opportunities to practice different approaches in class, such as those promoted by case studies, that would not necessarily have solutions, and if they do, those solutions are quite often not within the domain of science. The TCs' case study samples suggest success was achieved in (a) encouraging them to demonstrate understanding of SSI through case studies; (b) increasing interest in their teaching about SSI; and (c) challenging their ability to look beyond science standards. As elaborated upon by one TC:

Societal issues can be solved through science. I would like to explore it more, for sure, I hope to tackle issues within the classroom, or at least build in this approach … gets students to place values and ethics into what they are learning about … and make a choice. I think a lot of times, without an issues-based approach, students just learn content and are given material to memorize, but aren't pushed to have the opportunity to take a stand and create some action around what they are learning about.

Over the years, the instructor refined the assignment to include digital case studies that are interactive (including videos, images, simulations, etc.) and encouraged TCs to vary their presentation formats to include different genres (e.g., TED Talk, skits, Shark Tank parody, etc.), and as a result of its success, continues to implement it in science and STEM methods courses. Most recently it has been implemented in a science centre context, with the development of interactive digital case studies. These experiences prompt us to consider the preparation of future science teachers to tackle SSI in their classroom; in turn, they can better foster SSI with K-12 science students. Further, this assignment provides a useful framework for science teacher educators wishing to develop and conceptualize appropriate SSI assignments for science TCs.

Supplemental Files

Appendix-1.docx

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