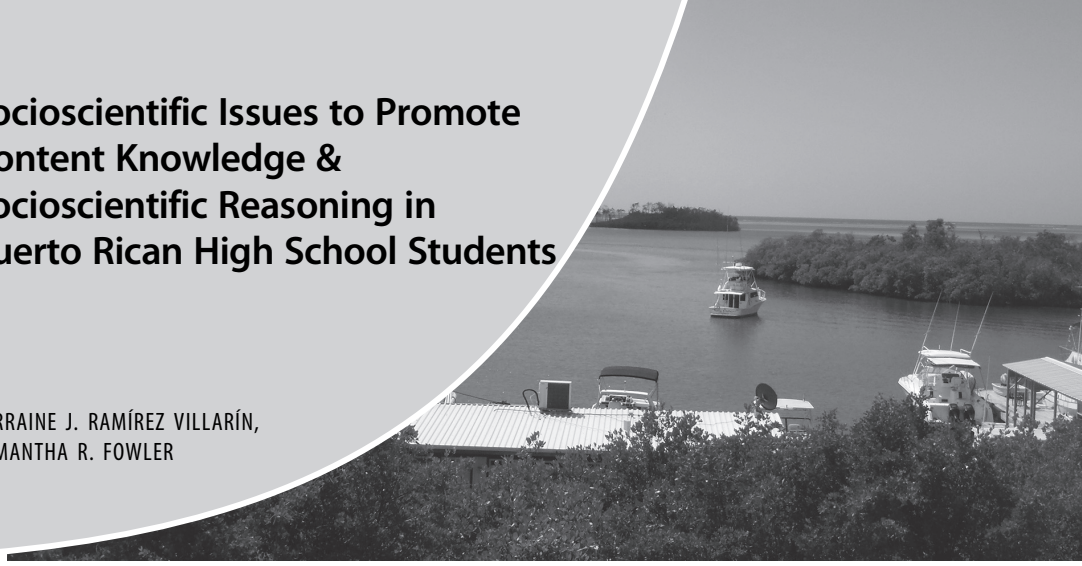
Socioscientific Issues to Promote Content Knowledge & Socioscientific Reasoning in Puerto Rican High School Students



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Abstract

Socioscientific issues have proved to be excellent tools for fostering the development of higher-order thinking skills that lead to superior socioscientific reasoning and decision making. This educational construct, with a focus on a local coastal environmental situation, was incorporated into a science class of high school biology students in Puerto Rico to assess relevant content knowledge and enable socioscientific reasoning. We describe how socioscientific reasoning was introduced, implemented, and assessed and the influence it had on students during a four-week in-depth exploration on the topic.

Key Words: *Socioscientific issues; socioscientific reasoning; relevant content knowledge.*

○ Introduction

Today's influence from the media, diverging ethical views among the population, and controversial political postures are overwhelming. Having scientifically literate students with the ability to analyze, synthesize, and evaluate information that can lead to making sound decisions regarding science and its relation to society is indispensable (Zeidler & Kahn, 2014). Content-based instruction, which allows students to learn terms and definitions needed to pass a standardized test, should be elevated to apply content to "real-world" contexts, which will enable students to face societal demands and the implications that come with them (Zeidler & Kahn, 2014).

Socioscientific issues (SSIs) are complex, open-ended narratives that feature the interdependence between science and society and are subject to multiple perspectives and solutions (Sadler & Zeidler, 2005; Zeidler & Kahn, 2014). Taking advantage of the fact that Puerto Rico is surrounded by water, an SSI on the deterioration of a local marine ecosystem and its conservation was created. Bioluminescence is a unique characteristic found in three major areas in Puerto Rico, including a recreational fishing village in the southwestern part of the island called "La Parguera." However, the luminous organisms at La Parguera have been critically threatened by impacts from urban development, coastal erosion, and human behavior. While some claim that houses on stilts erected along the coastline may have altered the living conditions surrounding these organisms (Valdés Pizzini & Schärer Umpierre, 2014), others disagree (Hertler, 2002). "Water folks" – nearby residents and fishermen – mention consistent boat traffic and improper policy implementation as contributing factors.

Controversial local environmental issues are not part of the Puerto Rican high school biology curriculum. As such, there are few educational resources featuring Puerto Rico. SSI education allowed us to incorporate a socioculturally relevant scenario in class to promote cognitive development by stimulating socioscientific reasoning (SSR) and decision-making skills. Tal et al. (2011) claim that value-laden SSIs support students in becoming active citizens because they combine the relationships between science and economical, health, environmental, and social issues, which Hodson (as cited in Tal et al., 2011) argues are missing from traditional teaching in most schools. Science content knowledge and application are tested through negotiation and discourse about SSIs as students realize these issues' relevance to the real world or, in this case, their island. Factors like culture and emotions play a significant role in the way individuals react to these issues (Zeidler et al., 2005). Therefore, the lack of access to such resources by these Spanish-speaking students presents a missed opportunity for inclusiveness in science education and studies. Through SSI negotiation, our goal was to promote SSR and the learning of relevant content while being exposed to a complex local situation.

This study compared changes in the science content knowledge domain and SSR of high school students in Puerto Rico faced with a local environmental issue. By incorporating an SSI into a structured, student-centered activity, relevant science content knowledge was expected to improve to a greater extent than with the traditional teacher-centered method. As students worked with a familiar issue, we hoped they would realize how science relates to

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situations around them, leading to an emotional attachment that would positively impact SSR, and more so in students negotiating with an SSI. We felt that finding relevance in the context of an area 45 minutes away from school would prompt awareness and motivate students to further explore the environmental issue, leading to a possible resolution.

Methods

This quasi-experimental "pre-post" study was done in a small private school in an urban area in the southwestern part of Puerto Rico. A sample of 100 students from 10th-grade biology and 12th-grade environmental science classes were part of this study. Parental consent was granted for 86 participants. The science teacher, with five years of experience and working on his master's degree, taught both courses through expository teaching or teacher-centered instruction. This was his first experience working with an SSI. He was trained and monitored daily by the primary investigator.

The four intact classrooms consisted of two 10th-grade and two 12th-grade classes. These groups were classified as "honors" or "regular" students. Those in the "honors" groups were considered to be academically talented students with a good grade point average in most subjects. Students in the "regular" groups had a history of mostly average to low academic performance. One 10th-grade "honors" group and one group of "regular" 12th-grade students became the experimental or SSI group; "the remaining "honors" group and "regular" group" became the control or non-SSI group. These groups were chosen randomly.

To assess relevant content knowledge and establish validity, a 20-item quiz, revised by two experienced college professors in biology and limnology, was administered as a pretest prior to the study. Scores ranged from 1 to 20. Items included terms related to marine ecosystems, bioluminescence, environmental policy, and facts about the area.

For SSR to be enabled, four dimensions need to be considered. Students should be aware of (1) the complexity of an issue, (2) the multiple perspectives it might bring, (3) how ongoing inquiry is essential, and (4) how to exercise skepticism (Sadler et al., 2011; Romine et al., 2017). The Quantitative Assessment of Socio-scientific Reasoning (QuASSR; Romine et al., 2017) provides a means to address each of these dimensions. Two items assess complexity, two assess perspective-taking, three assess inquiry, and three assess skepticism. However, in our study, SSR was measured as a unitary construct since students were working with an SSI for the first time and we wanted to address any changes in their reasoning. This instrument was answered online using Qualtrics software. Although the QuASSR has been properly validated by its developers (Romine et al., 2017), we validated the Spanish translation by having two bilingual experts review it. The instrument consisted of a concise SSI narrative on a coastal environmental problem in La Parguera, followed by a two-tiered, 11-item ordered set of multiple-choice questions. Credit was granted according to the level of SSR that the student chose from the alternatives provided. High-level SSR would receive two points, average-level SSR would receive one point, and basic-level SSR would receive zero points (Table 1).

The SSI for this study was about a controversy over whether or not stilt houses built along the coastline in La Parguera need to be removed due to concerns related to the natural flora and fauna of this marine ecosystem, including bioluminescence. Although some scientific studies suggest that the houses are harmless (Hertler, 2002), others blame their establishment for causing deterioration of the ecosystem (Valdés Pizzini & Schärer Umpierre, 2014). Both the SSI and non-SSI groups examined news articles about this environmental situation. However, the SSI group performed additional in-depth exploration, which included analyzing videos and scrutinizing environmental policy. As part of class activities, the SSI groups also learned about the Indian River Lagoon in Florida (which shares some parallels in coastal management) and efforts to restore it and compared the two situations. For two weeks, all the groups were taught key concepts about marine ecosystems, bioluminescence, coastal zone conservation and management, and environmental policy in Puerto Rico. The teacher combined lecture with inquiry and the use of assessments to impart instruction.

For the next two weeks, all students worked collaboratively in groups of four to perform different class-related activities. The team captain, appointed by the teacher, would assign roles to each member to challenge their perspectives while keeping a neutral standpoint as the information was evaluated. Students needed to gather evidence that would support their stance as if they were either a resident from the houses in question, an environmentalist, or a government agent. The non-SSI group compiled a portfolio with articles that would either favor or condemn the relocation of the houses and residents. An oral presentation on the articles and their opinions on the issue was made once the portfolio was completed. On the other hand, the SSI group worked differently. Students were divided into groups of four and appointed the same roles. However, they were randomly assigned which position to adopt even if it wasn't the one they shared. This would force students to be more open-minded about the situation. The exploration of the issue concluded with a debate on which formal, evidence-based arguments were anticipated.

On day 1 of this two-week period, the SSI group watched three 5- to 10-minute videos on the "Parguera" situation. The first one objectively spoke about environmental policy, the second one condemned the relocation of the houses, and the last one favored the relocation. Group members would then analyze the content of the videos and question their veracity. On day 2, the teacher provided students three online news articles that, like the videos, featured different positions on the issue. Afterwards, students had a chance to explore articles more suited to their stance. They worked collaboratively in the classroom and the computer lab for two more days to gather their thoughts and prepare their arguments. For the debate, students were evaluated using a four-point rubric based on the amount of justifications displayed and linked to factual evidence. Observations on attitudes and behaviors adopted by the participants were always made by the primary investigator during interventions with the SSI.

Once discussions and debate were completed, the posttests were administered. To measure whether teaching with an SSI on a local environmental issue increased relevant content knowledge, a dependent-samples t-test and a means test were performed. In assessing SSR, analysis of covariance (ANCOVA) was done to control for participants' prior knowledge.

Table 1. QuASSR items and scores based on students' socioscientific reasoning (SSR).

Response	High-level SSR (2 points)	Average-level SSR (1 point)	Basic-level SSR (0 points)
SSR complexity question: Are the problems in "La Parguera" easy to resolve?			
No	Because it involves balancing the economy with environmental action, legislation, and the possibility of relocating residents.	Because not enough information is provided. If more details were available, it would be easier to resolve.	N/A
		Because it involves the combined effort of the government, the residents, and the environmentalists.	
Yes	N/A	N/A	"La Parguera" is a tourist attraction and an economic engine for the town of Lajas. Restoration must be a priority.
			Conservation efforts should mimic those of the Indian River Lagoon. They are on the right path.
			An admission fee should be implemented to cover the costs of restoration.
SSR perspective-taking question: How likely is it that an environmental advocacy group and the residents of the stilt houses would endorse the same solution to this situation?			
Not very likely	The residents of the stilt houses and the environmental advocacy group have different concerns and points of view about the situation.	The residents of the stilt houses and the environmental advocacy group may have access to different pieces of information about the environmental situation of the area.	The residents of the stilt houses and the environmental advocacy group haven't had a chance to meet and come up with a plan.
Very likely	N/A	N/A	Both groups can work on finding a solution and coming up with a plan.
			A forum for open discussion between groups will foster reaching a solution.
			A neutral entity can listen to both parties and come up with a mediation plan.

○ Results

Content Knowledge

Pre-test quiz scores averaged 11 out of a possible 20, the lowest being a 5 and the highest being a 17, showing different levels of relevant scientific content knowledge on the topic. For the next four weeks, students learned and explored more about marine ecosystems and coastal zone management through lecture and article research. Posttest scores featured an average of 13, with scores ranging from 6 to 19, suggesting improvement for both groups; this was supported by a one-tailed dependent-samples t-test ($P < 0.05$). Due to this, means were tested to compare between the SSI and non-SSI groups. As seen in Table 2, means and standard deviations (SD) were 10.87 ± 3.20 (pretest) and 13.16 ± 2.63 (posttest) for the SSI group, and 11.54 ± 2.86 (pretest) and 13.11 ± 3.05 (posttest) for the non-SSI group. A z-test ($z < 0.05$) confirmed the significance of the higher gain observed for the SSI group ($P = 0.0372$).

Socioscientific Reasoning

Descriptive analysis did not reveal a favorable impact on SSR in the SSI group (9.21 ± 3.13 pretest vs. 9.07 ± 3.31 posttest), whereas the non-SSI group demonstrated improvement (7.95 ± 3.94 pretest vs. 9.30 ± 3.49 posttest) (Table 2). Unfortunately, the ANCOVA of data for SSR did not reveal significant changes between groups or after experience with SSI. These findings resemble those reported by Romine et al. (2017), in which content knowledge was positively impacted while SSR scores reflected no significant changes in students who negotiated with SSI.

Table 2. Descriptive analyses by groups (SSI = socioscientific issue, SSR = socioscientific reasoning).

Group	N	Content knowledge pretest	Content knowledge posttest	SSR total pretest	SSR total posttest
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
SSI	38	10.87 ± 3.20	13.16 ± 2.63	9.21 ± 3.13	9.07 ± 3.31
Non-SSI	47	11.54 ± 2.86	13.11 ± 3.05	7.95 ± 3.94	9.30 ± 3.49

Observations

Interestingly, students' outlook toward science seemed more positive among the low-achieving students than among the high-achieving ones. Moreover, good academic performance was not indicative of proper application and analysis, since most participants seemed inexperienced when it came to critical thinking and defending a position. Students' idea of debating consisted of repeating facts and statements once made by the teacher in lecture. Therefore, this wasn't a dominant skill prior to the study. During the debate, most 10th-graders managed to identify at least one line of justification while presenting their postures on whether to leave or relocate the stilt houses that are the focus of this controversy. Few students managed to convey two lines of justification.

The main themes during the debate revolved around political outrage and ethical views toward the issue. For example, students were visibly concerned that it wasn't right to force someone to relocate from a property they've had for years. Frustration grew as some students thought that environmental policy wasn't enforced fairly or properly, especially if residents were from an affluent financial background. These views overshadowed much of the scientific evidence presented in class or within videos or articles.

On the other hand, a sense of enthusiasm was mostly seen among the 12th-graders, as the debate gave them a chance to express themselves about the situation and build rebuttals against what didn't seem right. A sense of accomplishment was exhibited by many as they felt their claims or rebuttals had been successful. Every team managed to at least present one justification for their argument as the 10th-graders did. Those with more advanced understanding of the issue managed to deliver two or more formal justifications, using proper evidence to support their postures on the issue, although some relied on the material provided in lecture as a way to justify their claims.

○ Limitations, Implications & Recommendations

Once the study was completed, students were asked about their experience with the SSI. Participants responded that they had never worked with this type of negotiation involving an environmental local issue, even though the teacher usually made reference to local issues when pertinent. Among the two SSI groups, most of the students from the "honors" group were not pleased with the experience or the debate. They claimed the topic took too long and that they were not used to this kind of debate. On the contrary, students from the "regular" group enjoyed working with the SSI because it forced them to explore further, and they felt the best part was the debate. Nonetheless, this difference didn't seem to affect the outcome when measuring the content domain. Because greater understanding of the SSI led to a slightly higher gain in content knowledge, these findings support studies (e.g., Dori et al., 2003; Sadler et al., 2011; Zohar & Nemet, 2002) in which the use of case studies like SSI increased relevant science content knowledge. Although not exposed to the structured exploration done by the SSI groups, the non-SSI groups expressed wanting to work further with the local environmental issue since they found it interesting while reading about it during the QuASSR pre-test.

Negotiation through SSI fosters SSR. The four dimensions of SSR (see above) should be challenged, because participants' reasoning depends on how well these are addressed. Understanding the complexity of the issue, shuffling through the different perspectives or solutions the scenario might contain, inquiring about the reasons for justifying a claim, and becoming skeptical about the veracity of information were exercised during the debate as part of the discourse. Greater understanding of the issue led to a better quality of informal reasoning and use of justifications by participants. Structured claims were supported by at least one evidence-based claim representing a topic domain. Those exposing two or more justifications demonstrated greater insight on the issue. A study by Sadler & Zeidler (2005) found a similar correlation between content knowledge and reasoning while using SSI.

Unfortunately, a four-week in-depth exploration of an issue involving an SSI did not bring about changes in SSR. However, Sadler and Donnelly (as cited by Romine et al., 2017) believe that "an individual's understanding of a particular issue will likely influence SSR in the context of that issue." Given the proximity of the local issue, some students had relatives and friends residing in a stilt house, which made it easier for them to become empathetic about the issue. Others would visit or hang out in the area during the weekends or summer months, and it was a familiar place to practically all participants. This conflict of interest may have appealed to the ethical aspect and influenced their reasoning about the houses or the deterioration of the ecosystem. Although the QuASSR has provided similar results with a one-week SSI unit, a longer study in which an SSI is incorporated as part of a science class may foster the exercise of SSR as participants explore and debate various issues (Romine et al., 2017). In other words, an extended approach in which students assimilate the basic skills needed to apply SSR might provide a different outcome. Also, the difference in academic achievement between groups may have impacted results, given that high achievers' attitude toward negotiation with SSI was completely opposite from that of the low achievers. Student engagement among low achievers was far superior, as they seemed to enjoy a shift from the regular class routine.

Another benefit of this activity was displayed. Prior to SSI instruction, students seemed to be fixated on their beliefs and opinions and didn't consider other participants' points of view on the issue. Working with an SSI taught the students to be more open-minded and respectful of others' opinions, as reflected during the rebuttals provided in the debate. Similar observations were displayed in a study by Zeidler et al. (2018), in which answers to the SSI became more robust in description as participants acknowledged other viewpoints and exercised empathy.

Empowering future citizens to evaluate situations and make sound decisions that bring about positive change is highly recommended to aid in the reinforcement of critical-thinking skills that enable SSR. Boosting a science course by involving negotiation with an SSI that offers real-world scenarios, such that students can evaluate solutions and the social implications leading to a solution while applying science content, is doable but challenging. Lessons rich in critical thinking and discourse need teachers that can leave curriculum materials and instructional routines aside and become more flexible and resourceful (Zohar, 2007). These higher-order thinking activities involve shifting from a teacher-centered instruction of knowledge transmission to a more student-centered active instruction of knowledge constructors (Jiménez-Aleixandre, 2007).

Debates can bring about conceptual change but can also tap into the moral aspects and beliefs of the participants. According to Zeidler and Sadler (2007), "students' reasoning is greatly impacted by ambiguities or contradictions in the values of culture and context." The Puerto Rican culture and identity display a special appreciation for the island and everything that happens in it. The inclusion of a local SSI triggered an emotional reaction in students, being an issue they could relate to. However, different postures were adopted by students who lived or were closely related to the area and those who were not. While some based their arguments on concepts learned and the lack of policy enforcement, others defended residents' basic rights as a way to support the fairness of their decision.

Driven by these considerations, future studies will involve the use not only of local SSIs but also of foreign ones. As noted above, place and emotional attachment may be factors affecting SSR and decision-making skills when students are familiar with local scenarios. Moreover, these participants share the same culture and similar values, which may or may not affect their judgment. However, only one SSI was introduced to these students for which changes in debate and discourse abilities were observable. Including more SSIs related to topics covered in class should provide more opportunities for these future informed citizens to negotiate and apply relevant science content knowledge and present solutions to real-world situations not only in their island, but in other communities.

These Spanish-speaking students faced an open-ended SSI that promoted the content knowledge domain and student engagement, sparking an interest in topics related to environmental justice and sociopolitical inclusion. This activity challenged high-achieving and low-achieving students to exercise higher-order thinking skills that were lacking from a traditional teacher-centered, content-based classroom, thus fostering SSR.

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