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The development of primary school students' argumentation skills through socioscientific issues.

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Abstract

Scientific literacy is widely regarded as one of the most important goals of science education [1], [2], [3]. Socioscientific argumentation is considered a key scientific literacy competency whereby individuals justify their claims by verbally presenting a rationale for their actions when discussing every day issues [4]. Research indicates that teaching science through Socioscientific Issues (SSIs) has the potential to develop students' socioscientific argumentation skills. There is, however, a dearth of international literature on the impact of SSI in a primary/elementary school context. Within an Irish context SSI is not a feature of the Irish primary science curriculum and therefore an underutilized and under examined theoretical approach to the teaching of science. This study sought to explore whether the teaching of primary science through SSIs has an impact on enhancing primary school students' socioscientific argumentation skills. Seven primary school teachers and their classes (*n*=158 students) participated in this study over a six-month period. Findings indicate that teaching primary science through SSI enhanced students' ability to engage in socioscientific argumentation. In most cases students were able apply their science content knowledge and skills to socioscientific argumentation where students participated in discussions pertaining to a SSI relevant to their everyday lives. This study recommends that SSI education and socioscientific argumentation be an explicit feature of primary/elementary science curricula both nationally and internationally.

Keywords: *Scientific Literacy, Socioscientific Argumentation, Socioscientific Issues, Primary Science Education*

Introduction

Scientific literacy relates to how an individual uses their scientific knowledge and skills to participate as active citizens in society [5] and is widely considered to be the goal of science education [1] [6]. Many assert that SSIs can enhance scientific literacy developing the knowledge, skills and attitudes fundamental to participation in debates and decision-making issues that affect students' everyday lives [7] [8]. SSIs are considered to be complex multifaceted issues underpinned by science but also have social, economic, political and ethical considerations. They are tentative in nature and subject to ongoing inquiry where no definitive answer exists. The development of argumentation skills through SSIs is referred to as socioscientific argumentation [9] and is perceived to be a critical component of scientific literacy [5]. Argumentation is the process of arguing in which the construction, justification and refutation of arguments take place [10]. The development of student argumentation in the context of SSIs is appropriate as "argumentation is the activity subjects engage in when discussing controversial themes" in everyday life [10]. Providing students with opportunities for socioscientific argumentation is considered particularly important for science learning experiences [11] [12].

A small number of studies have explored the development and application of students' argumentation skills in a primary/elementary context which the majority of studies in this field situated in a secondary or tertiary context. For instance, findings from a study by Evagorou, Jimenez-Aleixandre and Osborne [13] indicated that the SSIs-based intervention was found to enhance students' (11-12 years old) argumentation skills, however, students were found to ignore scientific evidence when devising arguments. In a similar study, Khishfe [14] reported that explicit argumentation instruction through a SSI led to improvements in the students' argumentation skills with findings indicating developments in the students' ability to transfer their argumentation skills to unfamiliar SSIs contexts. Other studies concluded that even with specifically designed instruction students do not construct the high quality argumentation that might be expected of them [11] [12] [15]. Some have suggested that students often rely more on intuition and personal values when devising arguments and justifying claims and typically do not refer to scientific concepts and information in socioscientific debates [11] [13]. This has led to significant discussion on the position or value of scientific evidence in SSIs argumentation in the literature [16].

No study has examined the development of Irish students' argumentation skills in a primary/element school context. Argumentation is not a feature of the current Irish primary science curriculum with studies reporting that students have limited opportunities to engage in discussion as part of science class [17]. Furthermore, many of the argumentation studies that exist in an international field focus on small scale studies, using one SSI context, over a short period of time. This study sought to investigate developments in Irish students' socioscientific argumentation skills over a six-month period using six SSI units in seven primary/elementary school classes. The justifications provided by the students was of interest in this study as was the position of scientific evidence within the students' justifications. Findings from this study add to a growing field of literature on socioscientific argumentation and could be used to inform the revision of the primary science curriculum in Ireland.

Methodology

Seven primary school teachers explicitly taught socioscientific argumentation to their primary classes, hereafter referred to as cases, over a six-month period using six SSIs units. Students (*n*=158) socioscientific argumentation skills were measured through the use of a socioscientific scenario prior to and after the six-month intervention. Evagorou and colleagues [13] devised a scenario, questions and analytical rubric to analyse primary/elementary school aged students' argumentation skills in response to a SSI: Should we kill the grey squirrels in order to save the indigenous red squirrel? Adaptations of this were used for this study. It is important to note that this scenario was not taught as part of the SSI intervention. Students' written responses to the scenario were analysed using an adaptation of Evagorou et al.'s [13] argumentation analytical framework. Using this framework, students' responses were categorised and analysed according to the decision made and justification provided.

Findings

Students in all cases were asked to make a decision and provide a written justification for their decision pertaining to the SSI scenario 'Should we kill the grey squirrel in order to save the indigenous red squirrel'? Table 1 presents an overview of the number of students who provided a justification at the initial and exit stages of the study. Pre-intervention 43% of students did not provide a justification to support their decision. These students' responses include ones such as "Kill the grey squirrel", "We shouldn't kill it", "Die grey squirrel die" and "Yes shoot, trap or poison the grey squirrel because he is bad, so kill the grey squirrel". Post-intervention 86% of students provided a range of justifications for instance: "No. Try and solve the problem, Carry out tests on the grey squirrel. When you find something that works give it to all the grey squirrels through the acorns" or "Kill it because it is not native to Ireland and they carry diseases".

Table 1. *Number of students who provided justifications according to each case*

Case	***Pre-Intervention.*** *No. of students who provided a justification.*	***Post-Intervention.*** *No. of students who provided a justification.*	**Difference** *+ more - less*
A (4th class: 9-10 years old)	20 students (77%)	24 students (92%)	+15%
B (3rd class: 8-9 years old)	11 students (39%)	28 students (93%)	+54%
C (4th class: 9-10 years old)	15 students (58%)	23 students (92%)	+34%
D (6th class: 11-12 years old)	9 students (100%)	8 students (100%)	-
E (6th class: 11-12 years old)	18 students (82%)	21 students (95%)	+13%
F (3rd class: 8-9 years old)	0 students (0%)	7 students (54%)	+54%
G (3rd class: 8-9 years old)	11 students (47%)	16 students (70%)	+23%

Analysis of Table 1 indicates that in most cases (6/7) the number of students who provided justifications increased post-intervention. Case D is the only exception where all students in the 6th class provided justifications pre and post-intervention. A general pattern can be seen above where the cases with the least number of justifications pre-intervention made the largest increase in justifications post-intervention and the cases with the highest number of justifications pre-intervention made the lowest percentage of increases post-intervention. It could also be said that a greater percentage of students in the older classes (i.e. 6th class) provided justifications both pre and post-intervention.

Students' justifications in each case were then categorised into 'emotive', 'rationalistic' or 'emotive and rationalistic'. See Table 2 for a definition of each categorisation and illustrative sample from the students' written responses.

Table 2. Coding for students' justifications: Argumentation scenario

Code	Definition	Sample
Rationalistic	Describes reasoned based calculations. These include applications of cost-benefit analysis, rational assessment and limitations of technology.	*I think they need to gather more evidence and go investigate more before they make a decision*
Emotive	Application of moral emotions such as empathy and sympathy. People that use this seem to care about well-being of others.	*No because it's not fair. The grey squirrel is cute!*
Both emotive and rationalistic	Could be categorises as both reasoned based and an application of moral emotions	*No I like all animals and think it is wrong to kills any [emotive]. My approach to the situation is to keep the red squirrels in zoos and when they have loads of baby squirrels they can be released. It might take a while buy it will be better than killing them [rationalistic].*
No justification	No reason given to support the decision	*Kill the grey squirrel*

The number and percentage of responses categorised under each code is provided in Table 3.

Table 3. Categorisation of students' justifications as emotive or rationalistic

Case	Pre-Intervention Justification *No. (%) of emotive and rationalistic justification*		Post-Intervention Justification *No. (%) of emotive and rationalistic justification*	
A 4th class 9-10 years	20 students (77%)		24 students (92%)	
	Emotive 16 students (62%)*	*Rationalistic* 5 students (19%)*	*Emotive* 8 students (31%)*	*Rationalistic* 19 students (73%)*
B 3rd class 8-9 years	11 students (39%)		28 students (93%)	
	Emotive 7 students (25%)	*Rationalistic* 4 students (14%)	*Emotive* 5 students (17%)*	*Rationalistic* 25 students (83%)*
C 4th class 9-10 years	15 students (58%)		23 students (92%)	
	Emotive 13 students (50%)*	*Rationalistic* 3 students (12%)*	*Emotive* 7 students (28%)*	*Rationalistic* 17 students (68%)*
D 6th class 11-12 years	9 students (100%)		8 students (100%)	
	Emotive 4 students (44%)*	*Rationalistic* 6 students (66%)*	*Emotive* 1 student (12.5%)	*Rationalistic* 7 students (88%)
E 6th class 11-12 years	18 students (85%)		21 students (95%)	
	Emotive 8 students (42%)*	*Rationalistic* 12 students (52%)*	*Emotive* 4 students (18%)	*Rationalistic* 21 students (95%)
F 3rd class 8-9 years	0 students (0%)		7 students (54%)	
	Emotive -	*Rationalistic* -	*Emotive* 5 students (38%)	*Rationalistic* 2 students(15%)
G 3rd class 8-9 years	11 students (47%)		16 students (70%)	
	Emotive 4 students (17%)	*Rationalistic* 7 students (30%)	*Emotive* 1 student (4%)	*Rationalistic* 15 students (65%)
Total	57% of students provided justification (*n*=147)		86% of students provided justifications (*n*=147)	
	Emotive 52 students (45%)*	*Rationalistic* 37 students (25%)*	*Emotive* 31 students (21%)*	*Rationalistic* 106 students (71%)*

* If a student's response was categorised as both emotive and rationalistic it was put into two categorisations. Thus the total percentage may be over the total % for emotive and rationalistic justifications.

Findings indicate that not only did more students provide justifications in most cases at the exit stage of the study, there was a larger cohort of students who provided rationalistic justifications post-intervention. Pre-intervention three cases provided more emotive than rationalistic justifications, post-intervention all cases provided more rationalistic than emotive justifications with the exception of one case. Thus it could be said that the majority of students (57%) who provided justifications pre-intervention were doing so based on an emotive justification whereas post-intervention students' justifications became more rationalistic (71%) where many began to consider the role of evidence (social, economic, scientific) to help them make a decision and/or the role of scientists in coming up

with alternative solutions to the SSIs. The following are some examples of changes in students' justifications from pre to post-intervention to illustrate this movement:

Table 4. Examples of student socioscientific arguments from pre-intervention to post-intervention

No Justification (pre) "Kill the grey squirrel" (pre). **Student B31** ***Rationalistic (post)*** "Yes kill the grey squirrel. The red squirrel is native. The grey squirrel in not. The red squirrel is going extinct and there are plenty of grey squirrels in other countries. The grey squirrel is native to America" (post). **Student B31**
Emotive (pre) "Yes because red squirrels are nice and the grey ones are not; they are trying to kill the red ones" (pre) **Student A3** ***Rationalistic and Emotive (post)*** "I don't think the grey means to kill the red squirrel. We should trap the grey squirrel and test them to find out what disease they have. Scientists and doctors should make medicines or a vaccination" (post) **Student A3**
Emotive (pre) "No we should not kill the grey squirrel because both are nice on the inside" (pre) **Student C9** ***Rationalistic (post)*** "No. we need to plant more trees so that there are more acorns. We should make something that we will keep the acorns away from the grey squirrel until they are ripe" (post) **Student C9**

Discussion of findings

Findings from this study indicate that primary/elementary students can improve the quality of their arguments through explicit argumentation instruction in the context of SSIs. Pre-intervention over half the students decided to kill the grey squirrel with over 40% provided no justification to support their decisions and out of those that did provide a justification, the majority (62%) provided emotional justifications in the form of personal opinions or based on an emotional response without considering the evidence presented or questioning the necessity of additional evidence. Post-intervention the majority of students (64%) decided not to kill the grey squirrel. 86% of students provided justifications to support their decision. Out the justifications, 71% of students provided rationalistic reason-based arguments to support their decision where the students used the evidence presented, considered alternative solutions and/or sought additional information before making a decision in response to the SSI squirrel scenario. This echoes findings of other studies which have found SSIs interventions as effective in developing students' ability to provide logical and coherent arguments supported by evidence [11] [12] [14]. In addition, findings suggest that students, in most cases, were able to transfer their socioscientific argumentation skills from familiar to unfamiliar contexts, adding empirical data support this finding from Khishfe's study [14] in a primary school context.

The students use of scientific evidence to support their arguments post-intervention is in contrast to previous studies in socioscientific argumentation where students were found to 'ignore' scientific evidence if it was not in accordance with their own claims irrespective of class level, teacher, or cultural background [13] [18]. Many assert that students need opportunity to work collaboratively in groups, challenge each other's point of view, and engage in socioscientific discourse to enable students to consider all available evidence as part of the construction of an argument [14] [19]; the SSI intervention provided explicit opportunity for the students in this study to do so. This pedagogical approach is supported by others who have indicated that students need time and explicit instruction on how to form arguments [14] [16] [19]. Hofstein, Eilks and Bybee [20] further argue that providing students with opportunities to engage with and discuss SSIs develops skills that are important for student participation in societal debates concerning the development of their future as scientific literate citizens.

Conclusion

This study adds to the growing body of research on primary/elementary school aged children's capacities to engage in sophisticated socioscientific argumentation. Findings from this research indicate that the content of students' arguments enhanced from pre-intervention to post-intervention after explicit engagement with the SSIPSC intervention. In spite of this, research indicates that discussion, debate and arguments are not common features of the primary/elementary science classroom in Ireland [17]. This is perhaps not surprising given that argumentation is not an explicit

feature of the primary/elementary science curriculum [21]. If students are to engage in discussion pertaining to SSIs as scientific literate individuals, then students must be provided with explicit opportunities to do so. This study advances findings that SSIs are suitable contexts for the development of students' argumentation skills and should have a central position in primary/elementary science curricula and classroom practice.

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