**Exploring Elementary Students’ Socio-scientific Argumentation within an Ecosystem Related SSI-based Unit**

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**Abstract**

One of the overarching goals in science education is to prepare students to negotiate and resolve science-related everyday issues. Engaging students with argumentation practice in the contexts of socio-scientific issues (SSI) has been proven effective to address this goal. While prior studies have mainly explored students’ SSI argumentation at the secondary level, few focus on primary students. In this study, we address the gap and explore third graders’ SSI argumentation within an ecosystem related SSI-based unit. We used the mixed methods to study students’ SSI writings at three time points. To assess students’ SSI argumentation, we created a rubric from the argumentation and SSI literature as well as our initial data exploration. We used an iterative process to examine how well the rubric captured primary students’ SSI writing. The results show that with curricula support, primary students are able to develop sophisticated argumentation practice about complex issues. The findings also indicate that primary students’ SSI argumentation development is complex. There seemed to be interactions between sub-dimensions (e.g., science ideas vs.value) that are worth further research. Moreover, the scoring rubric has potential for better capturing students’ SSI argumentation practice, especially for young children, that feature both disciplinary norms and personal factors.

**Problem**

One of the overarching goals in science education is to prepare students to negotiate and resolve complex science-related everyday issues (e.g., DeBoer, 2000; NGSS Lead States, 2013). Engaging students with argumentation practice in the context of socio-scientific issues (SSI) has been proven effective to address this goal (e.g., Garrecht et al., 2021; Peel et al., 2019; Sadler & Donnelly, 2006). Issues such as climate change (e.g., Byrne et al., 2014; Dawson & Carson, 2020) and local water quality (Belland et al., 2015) provide an ideal context for students to justify or to refute claims with evidence from multiple perspectives or values. Different from scientific argumentation that mostly justifies disciplinary knowledge claims through empirical evidence, SSI argumentation draws on not only students’ prior scientific knowledge, but also their life experience, values, and personal identity (Balgopal et al., 2017; Oliveira et al., 2012). Therefore, one main feature concerning SSI argumentation is that there are no clear-cut resolutions that could be fully validated with empirical evidence. In addition, previous studies revealed that students across grade levels frequently rely on individual values or emotional attitudes, instead of science knowledge, when making personally related decisions (Albe, 2008; Lee, 2007). Although SSI argumentation has been broadly recognized as a higher order thinking skill, it remains challenging for teachers to enact the practice in classrooms due to factors such as lack of instructional time or available curriculum materials (Chen & Xiao, 2021).

While prior studies have mainly explored students’ SSI argumentation at the secondary level (e.g., Dawson & Carson, 2017; Khishfe, 2014), far less existing literature focuses on primary students. This might be so because young children lack the science content knowledge as well as argumentation skills necessary to effectively engage in debates about complex issues. However, we argue that young children have rights as community members to participate in society and make self-relevant decisions appropriate for their age. Furthermore, findings from the few existing studies also suggest that primary students are interested in and capable of engaging in SSI argumentation if they are provided with appropriate instructional supports (Byrne et al., 2014; Naylor et al., 2007). In this study, we address the research gap and explore third graders’ SSI argumentation practice within an ecosystem related SSI-based learning unit. This investigation was guided by the following research question: how do third graders’ SSI argumentation practices change over time in an ecosystem related SSI-based unit?

**Study Design**

This study took place in four U.S. 3rd-grade classrooms at the same school in a Midwestern city. The focal issue of the curriculum unit was the reduction of Monarch migration with an emphasis on ecological interrelationships within an ecosystem. The unit began with the driving question, “Should our school turn one of our soccer fields to a garden to attract butterflies?” At the beginning of the unit, students prepared written responses to the driving question—this product was designated as SSI writing 1. Next, students engaged in scientific practices including modeling to explore ecological relationships of an ecosystem of their choice. After exploring science content related to ecosystems, students were asked to answer the driving question again—this was SSI writing 2. The students were then introduced to the issue and discussed why Monarch migration numbers were decreasing. At the end of the curriculum unit, students were asked to respond to the driving question a third time—this was SSI writing 3.

This is a mixed-methods study (Creswell & Plano Clark, 2011) and the primary data source for this study is students’ SSI writings at three time points. To assess students’ SSI argumentation practice, we created a rubric (see Table 1) from the argumentation and SSI literature as well as our initial exploration of the data. We used an iterative process to examine how well the rubric captured primary students’ SSI writing. In the rubric, we identified four dimensions under SSI argumentation practice and assign different levels for each dimension. The science idea dimension represents how much science students incorporated in their reasoning and how accurate these science ideas are. The justification dimension is concerned with how well students used evidence to support and explain their positions. The perspective dimension relates to whether students are able to consider the focal issue beyond one perspective. The value dimension aims to capture the type of value students advocate as reflected in their SSI writings.

**Table 1. Scoring Rubric for SSI Argumentation**

|  |  |  |
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| **Dimension** | **Level** | **Description** |
| Science ideas | 3 | Uses science ideas appropriately |
| 2 | Uses science ideas but response reflects a misconception or confusion. |
| 1 | References a science idea but presentation is incoherent |
| 0 | Does not use science ideas to support response. |
| Justification  *.* | 3 | Multiple justifications are offered in support of the position and at least one of these justifications is explained/supported. |
| 2 | A justification is offered and explained/supported for the position that is taken. The justification is conceptually linked to the claim being advanced. |
| 1 | Limited justification is offered for the position that is taken |
| 0 | Provides no coherent justification for the position taken |
| Perspective | 3 | Analyzes the situation from multiple perspectives and offers a novel solution that combines the perspectives |
| 2 | Recognizes and rebuts a counter-position |
| 1 | Acknowledges a perspective beyond that taken by the student. |
| 0 | Reflects one perspective (that of the student) |
| Value | Personal | Value is oriented toward one’s own needs or interest |
| Anthropogenic/ Social | Value is oriented toward the needs of human communities |
| Ecological/ Naturalistic | Value is oriented toward preserving ecological relationships and/or nature |
| None | No values expressed |

Altogether, we collected SSI writing responses from 46 students across the four classrooms. Two team members scored the same 50% of the sample for interrater reliability. A 85% agreement of score was reached and all discrepancies were discussed and resolved. One team member scored the rest of the data set. All scores were input into SPSS for data analysis. We used a Repeated Measure ANOVA to examine changes in science ideas, justification, and perspective dimensions and Chi-Square test for the value dimension.

**Findings and Discussion**

In this section, we present changes in students’ SSI argumentation practice regarding the use of science idea, justification, perspectives, and their values. For each dimension, we illustrate the pattern with student examples.

**Use of Science Idea**

A Repeated Measure ANOVA was conducted on the students’ use of science ideas from the three time points over an ecosystem learning unit. The results from Table 2 indicated that students’ score on using science idea had statistically significant differences across the three points, F (2, 90) = 8.412, *p*<0.01. Post hoc analyses revealed that students’ score on the second time (*M*=1.15, SD=1.28 was significantly higher than the first time (*M*=0.413, SD=0.69). The third time (*M*=1.07, SD=1.04) score was also significantly higher than the first time. At the first time point, 31 of 46 students scored 0, which might be due to students’ unfamiliarity with science ideas related to ecosystem at the beginning of the unit.

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| **Table 2. Use of Science Idea (A Repeated Measure ANOVA)** | | | | | |
|  | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** | |
| Between groups (Time) | 15.01 | 2 | 7.507 | 8.412 | .000\*\* | |
| Within Groups (Error) | 80.319 | 90 | 0.892 |  |  | |
| \*\*. The mean difference is significant at the 0.01 level. | | | | | | |

Furthermore, it is interesting to note that students’ science score decreased from SSI writing 2 to SSI writing 3, though there was no statistically difference. In particular, 10 out of the 13 students who scored 3 during SSI writing 2 scored lower in SSI writing 3. We were not convinced that students’ science understanding about ecosystem became less sophisticated towards the end of the unit. Rather, we hypothesized that the decrease in students’ science score might be due to the following reason: students shifted their focus from science content knowledge to other dimensions such as personal value to make their arguments more convincing. The example below illustrates this pattern.

**SSI Writing 1 (S1)**: *Yes, [we should change a soccer field into a butterfly garden] so we can study butterflys and learn about butterflys see different colors* **(score 0)**

**SSI Writing 2 (S2)**: *Yes because they would have a place to live and to lay their eggs* **(score 3).**

**SSI Writing 3 (S3)**: *I want to make one of our soccer fields into a butterfly field. All of the butterfly colors of butterflies are so beautiful. The butterflies deserve a place to live in XXXX. They are kind to us they don't hurt us they get harmed from us because we are bigger than them. Butterflies have a reason to live at a school. The reason is –* **(score 0)**

The student (S1) did not use science ideas in their Writing 1 but used science ideas appropriately in Writing 2. However, in Writing 3, the student tried to use personal value and emotion (e.g., they are beautiful, they are kind to us) to make their point persuasive.

**Justification**

As Table 3 showed, students’ justification scores demonstrated statistically significant differences across the three time points, F (2, 90) =8.48, *p*<0.01. Post hoc analyses suggested that students’ justification score at the third time (*M*=1.65, SD=0.57) was significantly higher than the first (*M*=1.17, SD=0.57) and the second time (*M*=1.35, SD=0.64). But there was no statistically significant score difference between the first and the second time.

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| **Table 3. Justification (A Repeated Measure ANOVA)** | | | | | |
|  | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Between Group (Time) | 5.391 | 2 | 2.696 | 8.48 | .000\*\* |
| Within Groups (Error) | 28.609 | 90 | 0.318 |  |  |
| \*\*. The mean difference is significant at the 0.01 level | | | | | |

This finding suggested that during the ecosystem unit, students developed their argumentation skills to support their positions. For example, Student 2’s justification in SSI writing 1 was not supported or explained with more evidence. It mainly came from personal preference or curiosity. In SSI Writing 2, the student did not change his position, but advanced his justification by providing a reason that “baby catipillars they eat milkweed,” explaining the relationship between butterflies and milkweed. In SSI Writing 3, the student remained the same level of justification and supported his claim by deductively reasoning that the death of animals would be harmful to humans.

**SSI Writing 1 (S2):** *Yes because we have 2 soccer fields I want the old one as a butterfly garden because I wanted to learn about butterfly a lot and I wanna see milkweed* **(score 1)**.

**SSI Writing 2** **(S2):** *I still agree because I want to know about the butterflys habitat and why they need milkweed and why they tasted so bitter? Because then the baby catipillars they eat milkweed and milkweed taste so bitter* **(score 2)**.

**SSI Writing 3 (S2):** *I think its not a good idea to put a soccer field in a prairie because its ruining the habitat if you did do that. That's making animals die and when the animals die. It makes us die. Because animals are important to our lives if cows die we won't have any milk and if fishes die then it will ruin the water and we don't have anything we can drink. So please don't do that* **(score 2).**

**Perspective**

The quantitative results from Table 4 showed that there was a statistically significant difference in students’ perspective score over the three time points, F (2, 90) =5.842, *p*=0.004. Post hoc analyses found that the perspective score at the third point (*M*=0.72, SD=1.09) was significantly higher than the second time (*M*=0.2, SD=0.65), though there was no significant difference between the first and the second time.

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| **Table 4. Perspective (A Repeated Measure ANOVA)** | | | | | |
|  | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Between Groups (Time) | | 6.971 | 2 | 3.486 | 5.842 | .004 |
| Within Groups (Error) | | 53.696 | 90 | .597 |  |  |

The argument perspective score frequency suggested that most students persisted in stating their own positions (score 0, N=38, 42, 31) without considering other alternative perspectives. For instance, Student 3’s three responses were mostly limited in their own perspective.

**SSI Writing 1 (S3):** *Yes! I love butterflies and flowers* ***(score 0*)**.

**SSI Writing 2 (S3):** *Yes, we should because more butterflies will travel through MO and the population of butterflies traveling through MO will go up and I want the population to go up* ***(score 0)****.*

**SSI Writing 3 (S3)**: *Dear Mrs.H. I don't think the prairie garden should be destroyed because animals need a place to rest at night. And butterflys need milkweed to lay their eggs. The animals would die and you be destroying a habitat! Don't do it* ***(score 0)***

**Value**

A Chi-square test result demonstrated that there was a significant difference in frequency of values across the three times, *X2(2, N=138) =26.582, p*<0.001. Over the learning unit, 27 students switched to ecological value towards the end of the unit (N=27). Fourteen students’ values changed from personal needs or interest to ecological preservation.

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| **Table 5. Value** | | | |
|  | Value | df | Asymptotic Significance (2-sided) |
| Pearson Chi-Square | 26.582a | 6 | .000 |
| Likelihood Ratio | 28.469 | 6 | .000 |
| Linear-by-Linear Association | 18.780 | 1 | .000 |
| N of Valid Cases | 138 |  |  |
| a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 3.33. | | | |

For example, in SSI Writing 1 and 2, student 4’s main concern was his personal interest in playing soccer even though there were already two soccer fields. However, in SSI writing 3, he shifted his focus towards butterflies’ lives.

**SSI Writing 1 (S4):** *No. I said he should not because I like soccer* (**Personal**)

**SSI Writing 2 (S4):** *No I would not. I can not play soccer at my house* (**Personal**).

**SSI Writing 3 (S4):** *No because you all ready have one. Why would you want to have another one. We have to keep it so we could protect them or else they will no longer live* (**Ecological**).

**Contribution and General Interest**

In this study, we start to reveal how primary students’ SSI argumentation practice change pertaining to the use of science idea, justification, perspective-taking, and values. The results show that with instructional/curriculum support, primary students are able to develop sophisticated argumentation practice about complex issues. The findings also indicate that primary students’ SSI argumentation practice development is complex. There seemed to be interactions between sub-dimensions (e.g., science vs. value, justification vs. perspective) that are worth further research. In addition, the scoring rubric has potential for better capturing students’ SSI argumentation practice, especially for young children, that feature both disciplinary norms and personal factors (e.g., value, perspective). Given the focus on primary students’ SSI argumentation, this study should be of interest to the larger science education researcher community, and specifically those whose research is on socio-scientific issues, elementary science education, and elementary science teacher education.

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