A Case Study of Elementary Students' Argumentation in Science

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Abstract: This paper describes how a class of fifth-grade students from a Singapore school engaged in argumentation in Science through a computer-networked environment Knowledge Forum (KF). Extending over three months, the students' KF discussion focused on the rocky seashore ecosystem and its organisms. Fieldwork activities were incorporated to further trigger and sustain the online KF discussions in order to facilitate idea improvement and conceptual progress. Toulmin's Argument Pattern (Toulmin, 1958) was used as a tool to analyse the KF discourse pertaining to students' co-construction of arguments. Preliminary findings from this exploratory study indicated that the fifth-grade students could attain a reasonably good level of argumentation. Possible implications to inform the next cycle of the research study as well as for the teaching and learning of argumentation in Science lessons were also discussed.

Introduction

Researchers like Roschelle et al (2000) and Bransford et al (1999) indicate that students learn best when they are actively constructing new knowledge rather than passively acquiring knowledge. As students' knowledge construction starts from what they already know and believe, they bring into the classroom their common-sense understanding of the world that arises from their everyday life experiences. New understanding is derived when students articulate these ideas and negotiate new meanings through thoughtful and meaningful interactions with their peers and teachers.

Current literature on Science education reiterated the need to define meaningful Science learning "within a discourse of human agency" (Fusco & Barton, 2001, p. 342) that goes beyond "telling learners about a discipline" (Barab & Hay, 2001, p.70). Hence, learners are to do more of what real scientists do by immersing and collaboratively engaging in practices that mirror those of a collaborative research community of scientists. This is well encapsulated in Scardamalia & Bereiter's Knowledge Building approach (1994) whereby students post their own research questions and ideas for collective scrutiny in the Knowledge Forum (KF) database and work collaboratively to generate and improve intuitive explanations. Students thus become active agents in using and producing Science knowledge rather than passively imbibing scientific facts.

It is argued (Driver et al, 2000) that the reconceptualisation of the teaching and learning of Science in the light of the social constructivist perspective (e.g. Knowledge Building approach) necessarily puts forth argumentation as an important tool for students to critically examine and defend their Science ideas. Argumentation refers to the "dialogic process in which two or more people engage in debate of opposing claims" (Kuhn & Goh, 2005). It is the rational process of argumentation, not first-hand observations and experiments alone, that helps scientists in evaluating and critiquing the validity of experimental designs and the interpretation of evidence before accepting or rejecting knowledge claims. To better understand how students themselves could be engaged in argumentation for Science learning, several research studies (e.g. Erduran et al, 2004; Jimenz-Aleixandre et al, 2000) have developed different ways to support, analyse and assess argumentation in Science lessons.

This study investigated how a class of fifth grade students in Singapore engaged in a three-month online discussion of the rocky shore ecosystem using the Knowledge Forum platform. The proposed learning activity comprised a knowledge building component (enabled by Knowledge Forum) that was triggered and sustained by science fieldwork activities and tasks (enabled by IT tools like Tablet PCs and dataloggers). The fieldwork activities were conducted at the Labrador Beach in Singapore. The juxtaposition of fieldwork experiences with classroom knowledge building experiences (Scardamalia, 2004) was intended to motivate students to take increasing responsibility for developing their ideas, theories and explanations in the KF database in the light of fresh observations.

The intent in using Knowledge Forum was to give greater voice to learners during Science lessons and to devolve greater responsibility to learners in experimenting and working with Science ideas collaboratively. As the

KF database affords a visible record of students' conceptions (e.g. research questions, fieldwork observations, initial intuitive theories) at different stages of the project, it would be interesting to find out the extent to which students were able to collectively improve on their initial ideas over three months. From the outset, the study did not set out specifically to teach argumentation. The argumentative aspects in the KF discourse emerged during students' discussion of selected questions on the rocky shore ecosystem that required them to take oppositional positions. It was therefore more of a descriptive study to obtain a better understanding of students' argumentative strands in the KF shared space rather than an intervention study specially designed to improve the quality of their argumentation. Hence, the focus of this paper was on the analysis of the emerging KF argument patterns of the fifth grade students' online discussion:

1. How do students incorporate real-world empirical data from the fieldwork activities into the construction of arguments in KF?
2. How do students use argument operations (e.g. data, rebuttal) for the co-construction of arguments in KF?

Method

A case-study approach was used to explore the use of Knowledge Forum in a fifth-grade classroom of 40 students. The first author of the paper, with 9 years' of elementary school teaching experience, took on the dual roles of researcher and teacher to explore the knowledge building pedagogy with the students as well as to facilitate the fieldwork activities. The science teacher of the class acted as a facilitator during the fieldwork and some of the classroom activities.

Participants

The participating class of 40 fifth-grade students came from a well-established elementary school in Singapore. Though the students were considered to be of high-ability, they did not have prior experience with the knowledge building pedagogy, the Knowledge Forum platform and fieldwork activities. The students were introduced to the use of Knowledge Forum via two training sessions of about 2-3 hours each. It was also the first time that students were introduced to the rocky seashore ecosystem and to ecological concepts such as population, community and adaptations.

Design of the Study

Four phases **Connecting - Designing - Investigating - Constructing** (NWREL, 2002) were used to broadly scaffold the knowledge building processes and weave in the fieldwork activities (see Table 1).

Table 1: Phases of knowledge building and fieldwork activities

Phases	Online Knowledge Building (KF)	During Fieldwork
Connecting	Students raised initial ideas about the ecosystem based on four overarching questions (i.e. What is out there? Where are the organisms located? How much is out there? Why is it out there?)	
		First Fieldwork (What is out there? Where are the organisms located?) Students recorded on Tablet PCs what they observed about the ecosystem (e.g. organisms, zones, habitats)
	Students discussed their observations and raised further ideas or questions.	
Designing	Students designed a plan to provide an explanation, resolve a problem of understanding or guide an investigation.	

Investigating		Second Fieldwork (How much is out there?) Students carried out an investigation to collect empirical data about distributions of organisms using quadrats and Tablet PCs.
Constructing Meaning	Students organised and analysed their data and presented their findings. Students offered explanations, critiqued and refined ideas.	
Connecting – Designing – Investigating – Constructing Meaning (Why is it out there?) Students continued to critique and build on ideas. Based on the online discussions, each group initiated a question for investigation during the third fieldwork activity using dataloggers, sensors and quadrats.		

Though students worked in groups during the fieldwork activities, they were free to contribute to Knowledge Forum as a group or as individuals. The 4 broad inquiry questions were to help students spin off narrower lines of inquiry. For example, students discussed in KF the distribution of seashore organisms (Connect) before giving input on how the quadrat activity should be carried out (Design) during the second fieldwork to find some answers on distribution of seashore organisms. Students placed the quadrat, a one-metre square measuring device, along a straight line cutting through the different zones of the seashore to count the number of organisms living in the zones. The quadrat activity was carried out (Investigate) to provide some empirical evidence for students to further support or disprove the claims (Construct Meaning) they had posted in KF. Students also attempted to discuss possible sources of errors when carrying out their investigations. The fieldwork also served to trigger additional questions for discussion in KF.

Data Collection

The main sources of data collection comprised students' KF database postings and the relevant Analytic Toolkit data from KF. The former would determine students' argument patterns and the latter would reveal students' KF participation and contribution rates (e.g. number of notes written) in general.

Analysis Method

As some of the KF strands in this study required students to take oppositional positions to prove or disprove claims, the attempt was made in this paper to use Toulmin's model of argumentation (1958) as a method of analysing students' KF argumentative strands. The KF strand to be analysed is defined as "a cluster of notes that address a shared problem and constitute a conceptual stream in a community knowledge space" (Zhang, 2004). The components of an argument comprised (1) data (e.g. fieldwork observations, experimental results, facts), (2) claim (i.e. the position taken), (3) warrants (i.e. reasons justifying the connection between data and claim) and (4) backings (i.e. basic assumptions justifying the warrants) and (5) rebuttal (i.e. conditions for discarding the claim). An additional component is the qualifier which specifies the conditions for the claim to be true. Previous studies (e.g. Kelly, Druker & Chen, 1998; Jimenez-Aleixandre et al, 2000) had surfaced methodological difficulties in identifying and differentiating between the components of Toulmin's Argument Pattern in students' arguments. In addition, the coding of students' arguments in terms of Toulmin's argument operations was not able to shed light on the quality of the arguments. Hence, this paper utilised Erduran et al's (2004) categorisation of five levels of use of the rebuttals (see Table 2) to serve as indicators of the quality of the arguments. That is, rebuttals that directly address the evidences (e.g. data, warrants, backings) put forth in the claims are perceived to be higher-level argumentation rather than the combination of claims versus counter-claims. It is hoped that the identification of rebuttals according to the levels will provide teachers and ultimately students themselves with the means to evaluate arguments formatively and further improve upon them.

Table 2: Analytical framework for assessing the quality of argumentation

Level 1	Argumentation consists of arguments that are a simple claim versus a counter-claim or a claim versus a claim.
Level 2	Argumentation has arguments consisting of a claim versus a claim with either data, warrants, or backings but do not contain any rebuttals.

Level 3	Argumentation has arguments with a series of claims or counter-claims with either data, warrants, or backings with the occasional weak rebuttal.
Level 4	Argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims.
Level 5	Argumentation displays an extended argument with more than one rebuttal.

Results and Discussion of Findings

The argumentative KF strands came mainly from the discussions of two questions "There are many organisms living at the Labrador Beach. How can you tell whether they are plants, animals or non-living things?" and "Are plants and animals randomly located at the Labrador Beach or is there a pattern?" The first question was relevant to the elementary curriculum (e.g. students had been taught in Grade 3 the characteristics of land plants and animals) and to the students' first fieldwork experience. The second question extended beyond the elementary science curriculum and was related to the second fieldwork. To partly answer the first research question regarding the inclusion of empirical data, there were 45 notes in the views of the two questions above that explicitly included empirical data (Table 3). Empirical data included reported findings from fieldwork experiments and fieldwork observations (e.g. posting pictures of seashore organisms for identification and discussion). Though all 40 students participated in the fieldwork activities, not all of them contributed individual notes in KF.

Table 3: Students' contribution of KF notes and their inclusion of empirical data

Views	**No. of notes written**	**Percentage of notes built on by other students**	**Percentage of notes with empirical data (e.g. reporting results of fieldwork experiments, fieldwork observations or past experiences)**
Labrador Beach organisms - plants/animals/non-living things	106	43%	14.1%
Labrador Beach - random/pattern	148	54%	20.3%

The use of KF allowed students to post individual arguments or to co-construct arguments in the KF space for the two questions above. In answer to the two research questions, examples of the types and the quality of students' arguments from the preliminary analysis of selected KF strands are presented below:

Level 1 Argumentation

The first example shows a claim followed by a counter-claim with no supporting data or warrant for both claims. There is also no rebuttal.

PA: We think that the organisms are randomly located at Labrador Beach. If there is a pattern, it is not quite sensible **(claim)**.

ZT: No, we don't think so. **(counter-claim)**

Level 2 Argumentation

The second example shows an attempt to provide supporting data and warrant for the claim versus a counter-claim.

KE: After going to the Labrador Beach for the third time, we think that the organisms are placed randomly **(claim)**. If they are placed in a pattern, they would be easy for us and predators of theirs to find them **(data)**. They can also move around the beach freely **(warrant)**.

HJ: I disagree. Most of the nature's organisms or places are usually in the form of patterns, don't you realise!!! **(counter-claim)**

For both levels 1 and 2, it is clear that the absence of the rebuttal made it difficult for the students to progress beyond their current level of understanding as their beliefs remained unexamined.

Level 3 Argumentation

For the third example, the main claim "organisms are randomly located" are further supported by the second claim "If … pattern, isn't it easy for predators to find their prey" and its data "species become extinct". The rebuttal "species should know how to defend themselves" is considered to be weak because it does not directly address and connect to the main claim. However, FJ used his fieldwork observations (i.e. clumped together, stuck to one rock) as data to further support his counter-claim "animals are distributed in a pattern".

GE We still think that the organisms are randomly located **(main claim)**. It is that the waves may wash the organisms up on the shore or beach, scattering them at different places **(data to support main claim)**. If the organisms are scattered in a pattern, isn't it pretty easy for predators to find their prey??? **(claim 2)** Wouldn't a particular species become extinct if the predator discovers the pattern? **(data to support claim 2)**

FJ: The species should know how to defend themselves like the sea anemone. **(rebuttal to claim 2).**

FJ: I feel that the animals are distributed in a pattern **(counter claim)**. If the animals are randomly distributed…we would not find them clumped together **(data)**. During our trip to Labrador, we found many animals like the snails stuck to one rock **(data)** as there are abiotic factors the animals will gather together to take in the nutrients **(warrant)**.

Level 4 Argumentation

This example came from the KF discussion pertaining to differentiating between plants, animals and non-living things at the seashore. The rebuttal with its supporting data plays an important role in challenging claims 1 and 2 and thus changing the students' beliefs of how plants and animals were to be differentiated.

LV: <u>FOR KNOWING IF IT IS A PLANT:</u> it is USUALLY green, it USUALLY has signs of leaves, it USUALLY does not move FROM ONE PLACE TO ANOTHER, it is USUALLY stuck to something (soil/stone) and it USUALLY has no sign of animal parts (arms/legs/hands…) **(claim 1 + data + warrant + qualifier)**
<u>FOR KNOWING IF IT IS AN ANIMAL:</u> it NORMALLY moves about (needs to hunt for food/escape from predators), it NORMALLY has legs/arms/head....and something needs to move if the animal wants to move. MOVEMENT IS LEAPING, RUNNING, HOPPING, MOVING..... **(claim 2 + data + warrant + qualifier)**
<u>FOR KNOWING IF IT IS A LIVING THING:</u> If you touch it, and it reacts, it is likely to be a living thing **(claim 3 + data +qualifier)**.

FI: Your theory fits for most plants and animals as you put USUALLY but what are the theories that you can differentiate them without usually or rather ways of confirming that they are plants or animals **(rebuttal)**

GR: The main reason is plants can make their own food **(data to support rebuttal)**.

SA: We can test it out by using a leaf from a plant and a non plant…we can cover the leaves with iodine solution. The iodine will turn the starch blue black. Those parts of the plant's leaf which are blue black contain starch. The non plant will be yellow brown which shows that there is no presence of starch**…. (data to support rebuttal)**

Level 5 Argumentation

This example shows an extended argument with more than one rebuttal. FI also brought into the argument her fieldwork observations about sargassum and the colour of algae at Labrador Beach. FI's rebuttal at the end has the potential to lead her group to further examine the belief that "algae are plants".

ZY: If it is a plant, it should be green and should not move **(claim)**. If it is an animal it should be moving around **(data to support claim).**

MA: [I Need To Understand] Why do you say that plants do not move?
[New Information] Plants grow and by doing that, they are moving **(rebuttal 1)**.

SA Plants' roots also grow towards water **(more data to support rebuttal 1)**.

FI: [I Need To Understand] Why do you say that plants should not move?
[New Information] Plants respond to sunlight so they would probably need to move

towards the sunlight in order to receive more sunlight **(rebuttal 2)**.

FJ: I think that he [S1] means that moving around in the sense that you are walking around the beach **(qualifier to claim)**.

FI: [This Theory Cannot Explain] Not all plants are green, some like sargassum is brown. **(rebuttal 3)**

[I Need To Understand] Are algae plants? **(rebuttal to rebuttal 3)** In Labrador Beach, there are three kinds of algae…green, red, brown…

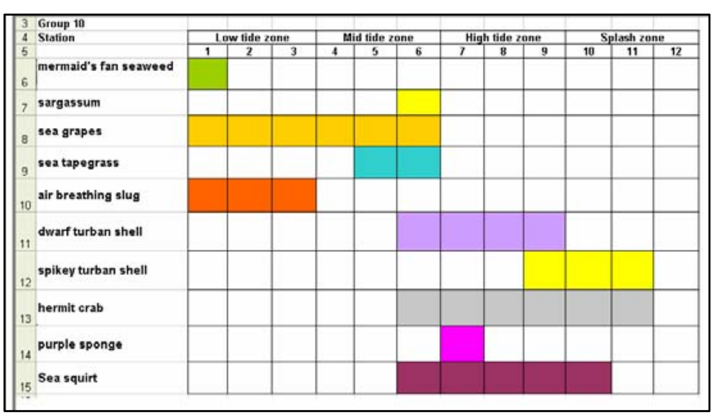
The evaluation of the quality of the students' arguments in terms of Levels 1 to 5 clearly showed the importance of the role of the rebuttal in challenging existing beliefs and assumptions in order to advance the knowledge of the community. The two examples of KF postings provided under Level 4 Argumentation and Level 5 Argumentation revealed how students skilfully incorporated their prior knowledge (e.g. what they already knew about land plants and animals to infer about seashore plants and animals) with their fieldwork observations and data to support or disprove the claims made about the seashore ecosystem and its organisms. Analysis of KF postings to determine possible trends in progression from Level 1 to Level 5 is underway.

The important role of fieldwork was also evident in the students' discussion of the second question "Are plants and animals randomly located at the Labrador Beach or is there a pattern?" Arguments in KF reached a "stalemate" (see Table 4) as the data given to support and disprove the opposing claims of distribution of seashore organisms seemed equally plausible in the eyes of the students.

Table 4: Students' KF postings to support/disprove opposing claims

Reasons for distribution in patterns	Reasons for random distribution
• We saw a lot of shells on a particular rock. • Some organisms like the dwarf turban shell stuck themselves onto the rocks and they do not get washed around • The hermit crabs were mostly found under the rocks and in holes. • What about the plants? They can't walk, so they should have a pattern.	• Most plants are light in weight and can be easily dispersed everywhere by the wind or water, hence not creating a pattern. • And, I still think that the animals are randomly located. The waves may wash the animals anywhere. • If they are placed in a pattern, they would be easy for us and predators of theirs to find them.

Data collected in the quadrat fieldwork activity was able to provide students with a more systematic overview of the distributions of the different seashore organisms. A few students began to use the quadrat data to rebut the claim that seashore organisms were randomly distributed (see Figure 1).



If it is randomly distributed, the organisms will be found everywhere rather than in certain zones **(rebuttal)**. We found that the quadrat **data** (on the left) showed that there is a pattern. The organisms survive where the abiotic factors they need are there. If not, even if they are washed/blown there, they will not grow **(data to support the rebuttal)**.

Figure 1. Quadrat activity provided data to disprove the claim of random distribution

Concluding Remarks

The use of Toulmin's Argument Pattern to trace the essential components of arguments, especially the rebuttal, will certainly help the students and the teacher to better understand how arguments should be constructed to facilitate knowledge advancement. Though the argument components are not explicitly taught in this phase of the study, groups of students did demonstrate manifestations of different levels of argumentation by their attempts to include relevant fieldwork data and results in supporting their claims. The fieldwork experience, by itself, is a necessary but not a sufficient condition to sustain students' KF discussion. Within the KF discussion, there is a need to pose questions which require argumentation to further challenge students' assumptions and fieldwork observations, thereby bringing about a deeper understanding of the phenomenon being studied. The next phase of the research study can focus more on a quantitative analysis of the different levels of argumentation as well as explore strategies for explicit teaching of the argument components. In addition, the KF scaffolds could be customised to explicitly support argumentation structures.

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