Abstract

Scientific argumentation is an integral part of learning science. In this small-scale exploratory study, we attempted to develop students' reasoning skill via the use of thinking routine of Claim-Support-Question whilst engaging students in the process of scientific argumentation. Paul's Wheel of Reasoning (1992) is the instrument used as a means to measure the quality of argument and hence student reasoning. This paper describes how the instrument is used to evaluate the quality of arguments and reasoning, discusses its strengths and weaknesses and makes recommendations for classroom instruction and further analyses. Preliminary findings as gathered from a grade-11 class has showed that by using CSQ routine and evaluating students' arguments, helped make their thinking visible in both their conceptual understanding and scientific reasoning, and promote collaborative discourses.

Keywords: scientific argumentation, claim-support-question, wheel of reasoning
Making Thinking Visible in classroom via Scientific Argumentation

Introduction
Over the year, we realised that students had difficulties writing effective explanations and making reasoned arguments. This problem was seen across all subjects. We found there were gaps in our student's argumentation and each department was solving this issue independently. This caused confusion among students as differently strategies were adopted by different subjects. We looked for a solution that could work across all disciplines and we found that Visible Thinking could be used to overcome all the issues we faced as a college.

We adopted the Claim-Support-Question thinking routine and Paul’s Wheel of Reasoning to scaffold critical thinking in the classroom. The aim was to teach argumentation in a consistent manner across subjects and to encourage debate, listen, define, question, to justify and encourage reflection.

Literature Review
Most of the articles on argumentation mentioned the importance of argumentation in science education. In Learning to Teach Argumentation (Erduan, Ardac, & Yakmaci-Guzel, 2006), the authors reiterated that not teaching argumentation in science, ‘exposes the weakness of science education’. Driver, Newton & Osborne (2000) mentioned that argumentation as a core practice in science, plays a critical role in advancing science knowledge.

Argumentation helps students to think critically. In Nussbaum (2002), he mentioned that the studying and practicing argumentation was to develop students’ capacity to engage in argumentation and reasoned discourse. In Dawson and Venville (2010), argumentation allowed individuals to be able to weigh up the risks and benefits, pose questions, evaluate the
integrity of information and make decisions. Adúriz-Bravo et al (2005) stressed that argumentation would allow students to identify problems, formulate hypotheses, contrast models, provide evidence, explain, justify and argue.

Most authors would recommend the use of a framework to help students scaffold their reasoning. Nussbaum (2002) mentioned that students require assistance in learning how to argue in a more explicit manner. Erduran, Ardac and Yakmaci-Guzel (2006) used questioning prompts and they modelled the strategy in class. While Dawson and Venville (2010) used a combination of questioning, writing frames and teachers playing the devil’s advocate and role play.

Students had difficulty in acquiring conceptual understanding in Physics. They often adopted the rote-memorization approach to learning Physics as they saw “learning” physics simply meant memorization of information and of problem-solving recipes that applied to highly specific situations‘ (Wiemann and Perkins, 2005). Studies (Venville, Dawson, 2010; Erduran, Simon, & Osborne, 2004) which involved students in argumentative discourses saw gain in the students’ conceptual understanding and reasoning abilities.

Recently, two more popular frameworks in teaching argument explicitly were works published by IDEAS project (Erduran, Simon, & Osborne, 2004) and the Claim, Evidence and Reasoning framework (McNeill et al, 2006). Both frameworks used Toulmin’s (1958) argument (TAP) structure, with some modifications; allowed students to gain experience in using the argument framework as well as using it to facilitate critical thinking and promote inquiry. While there were similar components such as claim, evidence (data) and reasoning which was comparable to warrant with backing; IDEAS framework emphasized on rebuttal.
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Methodology

Of the numerous and varied interventions done on argument and argumentation in the science classrooms, this study chose to focus on the means in developing reasoning competency in students using arguments. This is achieved through explicit teaching of a framework for argument to the students and then their subsequent applications of the framework. Hence, for the study, the thinking routine of Claim, Support & Questions was identified to familiarise students with a structure for making arguments and enhance students’ thinking. Our school has adopted the whole school approach in the use of Visible Thinking in action to enhance students’ learning. The learning goals of this argument activity for the students were: (a) to provide opportunity to acquire the structure of argument, (b) to construct the explanation to any given physics task using the CSQ structure, and (c) to have their argument evaluated using the modified Thinking Grid.

The following research questions guided the study:

To what extent has the structure of CSQ enabled the students’ quality of reasoning?

What is the quality of students’ argumentative discourse as they immerse in more argument writing experiences?

What is the learning gain in their conceptual understanding of the topics?

Gabrielsen (2013) cited J Osborne’s (of Stanford Graduate School of Education) argument that teaching students how to argue based on available evidence engages them in the scientific process and provides a better idea of how science actually works. He also highlighted that "argumentation," makes science education more valuable, not just for future scientists but for the public at large. With this in mind, we wanted to develop in our students
the ability to weigh up the risks and benefits, pose questions, evaluate the integrity of information and make decisions. We embarked on this project to see if our students with the right instruction and structure would be able to provide necessary evidence to support a claim and ask questions to test assumptions. Students have a tendency to just attempt questions in physics without questioning the assumptions or to question validity of the theory used. We wanted students to be critical thinkers and to make them better science students.

Subjects
Twenty-five Grade 11 students from an intact class that did Physics were involved in this argument activity. They were subjects of convenience sampling. They had done pure physics in their secondary school. These students have no idea what constitutes an argument, nor have experienced it as an instructional strategy, however, they may be familiar with the common exercise of explaining and have some notion of what is a scientific explanation.

Design
Use of Paul’s Elements of Reasoning
In the attempt to define critical thinking, Facione’s Delphi Study (1990) arrived at that critical thinking is a construction and evaluation of arguments (pp.5 – 10). As a result, the consensus statement has “critical thinking evolved to the ‘purposeful, self-regulatory judgement which results in interpretation, analysis, evaluation and inference as well as explanation of the evidential, conceptual, methodological or contextual consideration upon that judgement is based’ (Wu, 2008). Hence Paul’s Elements of reasoning (Paul & Elder, 1997) acts as a valid and good proxy to check on the quality of reasoning. The elements of reasoning (question at issue/claim, evidence, point of view, assumptions, inferences, implications, concepts) — constitute a central focus in the assessment of student thinking.
They are captured through students' writing made on the template and the classroom discourse as observed by teacher. The identification of claim and how well it is supported, decide one's scoring in terms of the quality of reasoning. This study adapted the Critical Thinking Grid as the scoring rubric for assessing students' reasoning ability. When it is used appropriately and graded accurately, it is reliable to give a high degree of consequential validity.

As this is a preliminary scan of the level of reasoning ability amongst the students and the ease of learning the structure of argument, there was only informal collection of classroom discourses by the teacher. As such, this study is predominantly quantitative.

The pre-test and post-test used the same questions. The test captured one short structured question for each topic (Dynamics and Turning effects of forces).

**Procedure**

The students did the pre-test without being exposed to the structure of thinking routine: Claim-Support-Question. In the pre-test, they completed the worksheet using the template (see Appendix 1). The completed templates were assessed using the Critical Thinking Grid rubric with the Elements of reasoning. For the subsequent lessons, teacher demonstrated how the argument structure is used, in the classroom using a teaching sequence. After a few weeks, another test was conducted, using the template. The results of the test are discussed in the next section.

This cycle was repeated for 2 different topics; namely Dynamics and Turning effects of forces.
Result and Data Analysis

A 2-tailed t-test was conducted for the mean scores of the students' responses in terms of (a) claim, (b) support & (c) questions on both topics.

Table 1: t-test on mean score of response for (a) claim, (b) support & (c) questions; for template on the topic of Dynamics

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1a</td>
<td>Q1b</td>
</tr>
<tr>
<td>mean</td>
<td>2.08</td>
<td>2.28</td>
</tr>
<tr>
<td>SD</td>
<td>0.954</td>
<td>0.980</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: t-test on mean score of response for (a) claim, (b) support & (c) questions; for template on the topic of Turning effects of Forces

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q2a</td>
<td>Q2b</td>
</tr>
<tr>
<td>mean</td>
<td>2.32</td>
<td>1.76</td>
</tr>
<tr>
<td>SD</td>
<td>0.988</td>
<td>0.831</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Graph 1_Dynamics: mean scores of responses for (a) claim, (b) support & (c) questions for pre- & post- tests.
Graph 2. Turning effects of Forces: mean scores of responses for (a) claim, (b) support & (c) questions for pre- & post-tests.

Findings and Discussion

For Q1a, Q1b, Q2a & Q2b, all have P values < 0.05. Hence, there is sufficient evidence to reject the null hypothesis for alternative hypothesis.

There is no P values for Q1c & Q2c as the students did not raise any questions in the Post-test. Students were confident in their solutions. However, they did question assumptions and concepts used during lessons.

For problem in the topic of Dynamics,

the mean value for ‘claim’ in the post test (2.84) is higher than pre-test (2.08) by 0.76. The increase is due to weaker students (weak in fundamental concepts) who performed better after the intervention (thinking routine) was introduced. They were able to identify the problem/issue or make inferences accurately. Stronger students maintained good performance for both test (not benefiting from the intervention).

the mean value for ‘support’ in the post test (2.84) is higher than pre-test (2.28) by 0.56. Weak students were able to give well developed evidence in the problem solving after the intervention. They were confident in applying concepts (Newton’s Second Law) and capable
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of presenting solutions in a logical way. Stronger students maintained good performance for both tests (not benefiting from the approach).

Similar results were obtained for the other topic ‘Turning effects of forces’. The post test results were better than the pre-test results for both ‘claim’ and ‘support’. Weaker students benefitted a lot from the approach (CSQ). The approach has actually provided a learning environment that both promotes and facilitates students’ construction, representation, and evaluation of knowledge claims and self-monitoring of scientific reasoning.

Stronger students did benefit from the ‘questioning’ part. Though they were good at problem solving, they lacked the ability to accurately identify assumptions initially. Most of the time they took things for granted without giving reasonable/valid assumptions. When teacher modelled on how to question assumptions accurately and reasonably during lessons. It was observed that they could ask deeper thinking questions after a few lessons.

It was also observed that students working in groups and having to reason about their opinions and teach one another and convince one another using the arguments that apparently convinced themselves. The approach (CSQ) has created opportunity for students to learn certain aspects of science that are different from conceptual comprehension.

Conclusion

In conclusion, the students have demonstrated good progress in using the structure of CSQ to enable their reasoning. Though the quality of students' argumentative discourse has yet to be established, it is obvious that rich discourses could be expected as they immerse in more argument writing experiences.

It is observed that students show improvement in conceptual understanding of the topics, and it remains to ascertain the learning gain.

Limitations and Recommendations
Initially the students had difficulty asking questions or to provide evidence to support the claims because to them this is seen as accurate and true and found it a waste of time. It took a lot of explanation and coaxing by the teacher to help the students to understand the need to question. The students had difficulty coming up with questions as they were uncomfortable in questioning scientific knowledge. As days went on students began to ask questions build on each other’s points of discussion enabling for deeper understanding of the topic.

One way to overcome this problem is to give students a list of question prompts to help them think of the questions to ask. Teacher could also model the questioning technique in the classroom and ask questions like ‘what if’ and ‘where did you get this idea’. When this is done, it would help make student’s thinking visible and others would start the cyclical process of examining point raised (which could be a claim, question or reason) through the CSQ routine.

Teacher could also verbalise the concept to help the students to meta-cogitate – activate their thinking on what was being verbalized and to further help along the process use Paul’s Wheel of Reasoning to help to facilitate thinking and reasoning.
References


The Critical Thinking Grid, (n.d.) Critical Thinking & Assessment, retrieved from
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Appendix 1

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### Pre-test

**Dynamics**

**Claim:**

**Support:**

**Question:**

### Turning effects of forces

**Claim:**

**Support:**

**Question:**

Appendix 2

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A cubic piece of cork of sides 2.00 cm was placed in water as shown in the diagram below.

Given that the density of cork is 200 $kgm^{-3}$, calculate the upthrust on the piece of cork.

Calculate the height of the piece of cork above the water.
(density of water = 1000 $kgm^{-3}$)
<table>
<thead>
<tr>
<th>Competency</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify the claim/ problem/ question at issue.</td>
<td>Accurately identifies the problem/question</td>
<td>Identifies the problem/question. Makes insufficient inferences</td>
<td>Identifies an inappropriate problem/question. Makes inaccurate inferences</td>
<td>Does not identify a problem/question Makes inappropriate inferences</td>
</tr>
<tr>
<td>Identifies and assesses the quality of supporting data/evidence</td>
<td>Provides a well-developed examination of the evidence and questions its accuracy, relevance, and completeness.</td>
<td>Examines evidence and questions the quality.</td>
<td>Merely repeats information provided. Does not justify position.</td>
<td>Does not identify or provide relevant supporting evidence.</td>
</tr>
<tr>
<td>Identify and assess the questions raised</td>
<td>Identifies and evaluates relevant significant points of view</td>
<td>Identifies and evaluates relevant points of view</td>
<td>Identifies other points of view but may focus on irrelevant or insignificant points of view</td>
<td>Ignores or superficially evaluates alternate points of view</td>
</tr>
<tr>
<td>Points of View</td>
<td>And/Or</td>
<td>And/Or</td>
<td>And/Or</td>
<td>And/Or</td>
</tr>
<tr>
<td>Assumptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurately identifies assumptions (things taken for granted). Makes assumptions that are reasonable, valid</td>
<td>Identifies assumptions.-Makes valid assumptions</td>
<td>Fails to identify assumptions, or fails to explain them, or the assumptions identified are irrelevant, not clearly stated, and/or invalid</td>
<td>Fails to identify assumptions. - Makes invalid assumptions</td>
<td></td>
</tr>
<tr>
<td>And/Or</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interpretation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurately identifies assumptions (things taken for granted). Makes assumptions that are reasonable, valid</td>
<td></td>
<td></td>
<td>Uses superficial, simplistic, or irrelevant reasons and unjustifiable claims</td>
<td></td>
</tr>
<tr>
<td>And/Or</td>
<td></td>
<td>And/Or</td>
<td>Misunderstands key concepts or ignores relevant key concepts altogether.</td>
<td></td>
</tr>
<tr>
<td>Concepts</td>
<td>And/Or</td>
<td>And/Or</td>
<td>And/Or</td>
<td>And/Or</td>
</tr>
<tr>
<td>Identifies and accurately explains/uses the key concepts</td>
<td>Identifies and accurately explains and uses key concepts but not with the depth and precision of ‘4’.</td>
<td>Identifies some (not all) key concepts, but use of concepts is superficial and inaccurate at times</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>