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Argumentation in Singapore Science Teaching:

What Do Teachers Think?

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Abstract

Argumentation is increasingly recognized both as a central scientific practice and important science pedagogy for critical thinking (CT) in students of all abilities. Although previous research has investigated other aspects of critical thinking and Normal Technical [N(T)] classes, little is known about what Singapore science teachers believe about using argumentation for N(T) students and how this is related to their pedagogical beliefs. The investigation aimed to find out how teachers' opinions of the effectiveness and their likelihood of using argumentation varied depending on: the characteristics of possible argumentation activities; whether these were correlated with the teachers' background; their pedagogical preferences; the ways they preferred to interact with students; and the resource support they received. 32 N(T) science teachers from 18 secondary schools responded to an online research survey containing 14 argumentation-based activities of varying levels of argumentation, topic and question format. A moderate but significant overall difference was found in teachers' perception of their pedagogical effectiveness and the likelihood of their use for argumentation in N(T) compared to Express classes, regardless of argumentation level, topic or question format. Teachers also perceived CT activities as the least suitable pedagogy for N(T) classes. Teachers' experience, rapport with students, proportion of class time spent on CT, and quality/sufficiency of N(T) resources were significantly correlated with likelihood of using argumentation. These findings potentially guide the introduction of argumentation into Singapore science teaching, and highlight the importance of school support and teacher-student relationships in the process.

Argumentation in Singapore Science Teaching: What Do Teachers Think?

Introduction

*“Argumentation is a genre of discourse central to doing science and thus is central to learning to do science.” (Duschl & Grandy, 2008, p. 34)*

*“... people just memorised, copy paste answer [sic] from the book and congratulations, they have their distinctions. I kept thinking why, why, why ... you just knew that this wasn't right.” – Carol, a former Singapore Normal (Technical) student (Ho, 2012, p. 114)*

While science education academics have amassed a body of research to point the way forward in science teaching, particularly about the growing importance of argumentation (Osborne, 2010), voices from the ground indicate that reality may be far from the vision, as the quotes above illustrate. What, then, do our science teachers, as gatekeepers of our students' educational experiences, believe about argumentation?

The centrality of argumentation

Argumentation is a social process of advancing and refuting arguments, requiring the consideration of claims, evidence and reasons. It is a collaborative, interactive negotiation of meaning (Chin & Osborne, 2008, p. 4).

Fundamentally, the question to address is – why argumentation? Is it merely another pedagogical fad alongside the numerous that have emerged in the past century? But as illustrated in Figure 1 - Three Spheres of Scientific Activity (National Research Council, 2012) below, argumentation and critique lies at the heart of the scientific peer review, the core mechanism by which hypotheses become theories (Driver, Newton, & Osborne, 2000).

Without argumentation, scientific concept development as we know it would be impossible (Zeidler, Osborne, Erduran, Simon, & Monk, 2003), because argumentation is the *language of science* (Tippett, 2009, p. 29). Such has led the historian Crombie to observe that “the history of science has been the history of vision and argument” (Crombie, 1994).

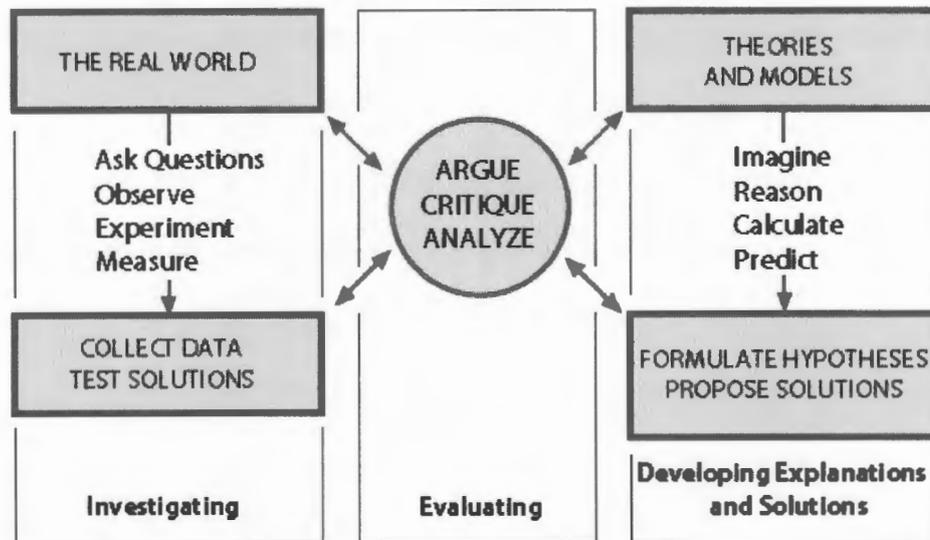


Figure 1 - Three Spheres of Scientific Activity

Therefore, using argumentation in science teaching not only better reflects the nature of scientific work, potentially piquing the interest of students to pursue science or engineering at higher levels, it also foregrounds the epistemological basis of science (Driver et al., 2000) by tapping on critical thinking (CT) habits of mind consistent with scientific attitudes. For instance, the development and evaluation of arguments has been cited as the operational definition of CT (Facione, 1984, p. 259). If we indeed hold that “Critical and Inventive Thinking” are skills “necessary for the globalized world we live in” (Singapore Ministry of Education, 2010), then the case for argumentation in the context of the Singapore science classrooms naturally becomes stronger. This study, then, becomes important in determining teachers’ views about argumentation, and where perceived adoption barriers are. In doing so,

it hopes to point the way for future research to facilitate the adoption of argumentation in Singapore science classrooms.

*Argumentation for various streams and age groups*

Potentially, one could state that if argumentation being CT is higher-order thinking, then it could be “too higher-order” for some pupils, a pertinent concern given that Singapore’s classrooms are not monolithic but banded or streamed from Primary 5 onwards. Some point to Piaget’s theories of elementary students as concrete thinkers (Piaget & Inhelder, 1958) as substantiation, and also object that complex intellectual activities such as argumentation imposes a cognitive load that is too heavy on some learners (Sweller, 1994, pp. 300–301), resulting in slow and error-prone performance. If such concerns are valid, argumentation should then be confined to older or “higher-ability” students.

Yet, it is also apparent that young children of all ages are quite good at arguing in the appropriate context (Anderson, Chinn, Chang, Waggoner, & Yi, 1997, p. 166; Aufschnaiter, 2004) and are able to identify argumentation structures in written text (Chambliss & Murphy, 2010) without specialized training. Indeed, training through sufficient practice spurs cognitive growth. This has been seen to occur even in young children (Eberbach & Crowley, 2009, p. 59; Mercer, Dawes, Wegerif, & Sams, 2004) and low-ability learners, who can make substantial gains when they learn science through activities involving CT skills such as argumentation (Cuevas, Lee, Hart, & Deaktor, 2005; Kuhn & Udell, 2003, p. 1256; Lee, 2002, p. 54; Mercer et al., 2004, p. 375; White & Frederiksen, 1998, p. 74; Yerrick, 2000; Zohar & Dori, 2003). Given this body of evidence, it is more likely the case that all pupils, regardless of age or perceived ability, can participate in higher order thinking like argumentation.

*A progression of argumentation levels*

One important implication from the preceding section is that the demands of argumentation on the learner are within the educator's power to vary in the context of any task, thereby adjusting the difficulty suitably for different-ability students. In order to do so, we now address the issue of how to articulate discrete levels of difficulty in argumentation. This issue has also been previously addressed by Berland and McNeill (2010) in their proposed learning progression for argumentation that allows for the holistic consideration of the dimensions of instructional context, argumentative product, and argumentative process. From their observations, these dimensions of argumentation are not age-dependent – there are examples where younger students have greater progress compared to older ones (2010, p. 790) – and this agrees with results of studies mentioned in the preceding section.

*Argumentation Progression Map*

However, to address the pressing concern of the cognitive load of argumentation, we adopt the progression proposed by Osborne, Henderson, MacPherson, Szu, & Wild (2014, pending publication), in **Appendix 1: A Progress Map for Argumentation/Scientific Reasoning**, which focusses on the cognitive processes undergirding a single argumentation event of one learner, within the overall context of an argumentation activity. The level of competency in argumentation can be notated using the Argumentation Progression Map where 15 levels of complexity are mapped based on the cognitive load of having to simultaneously coordinate elements of claims, warrants and evidence. For instance, at level 0, there is no evidence of any argumentation facility, with consideration of claim, evidence and warrant being implicit at best. Whereas, at the highest level  $2^{(N-1)}$ , counter claims with justification are constructed together with consideration of additional pieces of evidence to contrast against a competing argument.

*The need for argumentation in Singapore science*

Having outlined the theoretical framework for argumentation, the question arises whether it is relevant for introduction in the Singapore context – especially as Singapore already has the one of the highest TIMMS and PISA scores for science in the world. Would it be as the Chinese idiom goes – “adding legs to the painting of a snake”, introducing an unnecessary extra into a virtually perfect system? While indeed it is true that Singapore does have very high averages, there is also a long tail to the distribution of achievements – low-performing students lack significantly behind the average (OECD, 2011, p. 7). Given the evidence that argumentation may be beneficial also for low-ability students, it is therefore timely to consider whether argumentation could therefore be feasibly introduced not just to stretch our high-ability students, but pertinently to help close the achievement gap in science for the low-ability students in Singapore – our Normal (Technical) learners.

## Addressing the Normal (Technical) Learner

Previous studies have focused on the dispositions of Normal (Technical) or N(T) learners<sup>1</sup> and the tone of their classroom environments (Ismail & Tan, 1997; Ang, Neubronner, Oh, & Leong, 2006). While their challenges within and without the classroom are somewhat known, study of students in the N(T) track that have since achieved academic success suggests that these students need to be engaged in intellectually challenging, socially supportive and connected ways of learning and understanding (Ho, 2012, p. 118). This finding agrees well with other findings that both intellectual quality and supportive practices in present in both classroom pedagogies and work expectations have a close correlation with academic performance (Lingard, Hayes, & Mills, 2003, p. 410). Ho found that there was a mismatch between the institutionalized ways of learning where students were expected to

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<sup>1</sup> N(T) students are the low-track students in Singapore secondary schools (7<sup>th</sup> to 10<sup>th</sup> grades). They are streamed into separate, dedicated classes after the 6<sup>th</sup> grade Primary School Leaving Examinations.

memorize, and their personal learning expectations. They were not a “memorizing sort of (people)” but needed to understand, even if they took more time than others to do so (Ho, 2012, p. 114).

### *Normal Technical students and their teachers*

If the cultural habitus of the N(T) science classroom is owed in part to the role of teachers, it is then important to understand what their pedagogical beliefs and practices are like, and whether these are conducive for the introduction of science argumentation for their low-track pupils. Not much is written specifically about teacher receptivity towards argumentation. Firstly, there is a need to find out if there are differences in teachers’ perception of N(T) and Express currently exist, potentially leading to an “advantage effect” where higher track students may have greater access to CT activities than lower track students (Raudenbush, Rowan, & Cheong, 1993). Secondly, there is a need to find out if “external” factors like teacher background, pedagogical beliefs, student- and school-related factors may influence the teachers’ response to argumentation. Taken together, these are factors that may exert significant influence on whether implementation of any argumentation-infused curriculum would be successful.

## Research Design

### *The Survey Instrument*

A survey research approach was chosen because direct classroom observations of argumentation activities are of little value at this stage, given that at present, there are no known instances where argumentation is currently practiced in low-ability Singapore science classrooms.

To reduce inaccuracies due to self-reporting, participants were instead presented with a series of vignettes describing different levels of argumentation being utilized, in order to

obtain their views on the suitability of the tasks. This parallels the approach taken by Torff, who developed the *Critical Thinking Belief Appraisal (CTBA)*, a 6-point Likert-scale survey to find about teachers' CT beliefs (Torff, 2008), by presenting various CT vignettes that typify low or high CT activities, and asking teachers about their suitability for either low- or high-ability students, low- or high-content knowledge students, and low- or high-motivation students.

The vignettes are pegged to the Argumentation Progression Map (Osborne et al, 2014 — Appendix 1: A Progress Map for Argumentation/Scientific Reasoning). 14 vignettes were produced, based on 8 of the 15 levels in the map, from level 0a to level 1d. Level 0, which could be summarized as no explicit evidence of any claim, was excluded as being too basic. Higher levels (2 and above) were excluded for this study.

In each of the vignettes, a curriculum resource is used as the point of discussion in the activity. The format of each of the curriculum resources is based on one of 3 types of resources – Table of Statements, Competing Theories - Ideas and Evidence, and Constructing an Argument; that were in turn selected from a larger list of nine (Osborne, Erduran, & Simon, 2001, p. 10). These three were most easily adapted to the vignette form, and Singapore teachers would generally be familiar with these, as they are similar to the format of resources used for both instruction and assessment.

The curriculum resources were based on the N(T) topics of forces, electricity and digestion. These three topics stem from both physical and life sciences, and included in both lower- and upper-secondary N(T) science (Singapore Ministry of Education, 2014), unlike other topics, and thus facilitate both lower- and upper-secondary N(T) teachers in finding relevance in the curriculum resources.

Table 1 below summarizes how the 14 curriculum resources were distributed by argumentation level, curriculum resource format, and topic. Considering that eight levels of

argumentation, three types of formats and three topics potentially allowed 72 different resources, which would be impractically numerous, the table also illustrates the trade-offs that were necessary for the purpose of this survey-based research.

Table 1 - Each entry in the table below represents a question being asked about the effectiveness of a curricular resource. The "(O)" besides a topic means that questions about that curricular resource will also include an open-ended question.

Level	Table of Statements	Competing Theories – Ideas	Constructing Arguments
0a		FORCES (O) <a href="https://docs.google.com/document/d/1fob9te">h.1fob9te</a>	<p>DIGESTION</p> <p><a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.4d34og8">https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.4d34og8</a></p>
0b	DIGESTION (O) <a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.1t3h5sf">h.gjdgxs</a>	<p>ELECTRICITY<a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.1t3h5sf">https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.1t3h5sf</a></p>	
0c	<a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.1t3h5sf">h.2s8eyo1</a>		<p>FORCES<a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.1t3h5sf">https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit-heading=h.1t3h5sf</a></p>

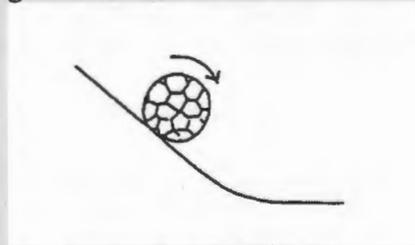
		<a href="#">VZ6ykfRofrTX5KRi2fSjQ</a> <a href="#">/edit - heading=h.lnxbz9</a>
0 d	FORCES <a href="#">h.3dy6vkm</a>	ELECTRICITY (O) <a href="#">h.2et92p0</a>
1 a	DIGESTION <a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.3rdcrjn">https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.3rdcrjn</a>	FORCES (O) <a href="https://docs.google.com/document/d/1yv7grK7RC KYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.35nkun2">https://docs.google.com/document/d/1yv7grK7RC KYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.35nkun2</a>
1 b	ELECTRICITY <a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.17dp8vu">https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.17dp8vu</a>	FORCES (O) <a href="#">h.3znysh7</a>
1 c	DIGESTION <a href="#">h.30j0zll</a>	ELECTRICITY (O) <a href="#">h.tyjcwt</a>
1 d	DIGESTION (O) <a href="https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.26in1rg">https://docs.google.com/document/d/1yv7grK7RCKYUVX1iSDqJxmVZ6ykfRofrTX5KRi2fSjQ/edit - heading=h.26in1rg</a>	

*Argumentation Vignette*

An example of a vignette (Resource 13) is given below in Figure 2. This is in the Constructing Arguments format and based on the topic of Forces and pitched at argumentation level 1a. Although it looks like an activity that merely requires students to construct an explanation and justification, this is in fact a description of argumentation at level 1a: “students need to coordinate one explicit logical connection between claim and evidence by way of a warrant” (**Appendix 1: A Progress Map for Argumentation/Scientific Reasoning**). It should be recognized that the actual argumentation happens in the course of the discussion activity; the handout itself facilitates argumentation by focusing the class’s attention on a certain level of argumentation.

*The teacher provides students with the following handout.*

A beach ball was placed on a hill without being pushed. It starts rolling down the hill, and gets faster and faster.



Name one force acting on the ball.

State one reason for your answer in (a).

*The students are given time to answer the question individually. The teacher then asks the students to pair up and share their answers with each other, before leading a short class discussion, where students are asked to share their answers and reasons with the whole class.*

*The teacher is using this activity to teach how to predict changes in speed and*

*direction when a force acts on an object.*

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Figure 2 - Example of Argumentation Vignette

All of the vignettes also state a learning outcome which is aligned to a learning outcome under the “Knowledge with Understanding and Applications” category of the N(T) Science Syllabus. For example, the vignette above stated that the teacher was using that activity to teach how to predict changes in speed and direction when a force acts on an object. Providing the learning outcome suggests to participants that argumentation skills and processes could potentially be used for teaching of content, and facilitates participants in evaluating effectiveness of the resource for achieving learning.

#### *Participant Profile*

The participants were 32 teachers from 18 Singapore secondary schools, out of 133 public (government or government-aided) schools that offered the N(T) course in Singapore. Although the majority was rank-and-file teachers, many of the participants (40%) also held leadership positions within the school.

Most of the teachers were relatively young in terms of experience, with about two-thirds with 10 years of experience and lesser (see Figure 3 below), with the vast majority having taught all 3 tracks – Express, Normal (Academic) and N(T). It is remarkable that about ¼ of participants were also beginning teachers with less than 3 years of experience, yet assigned to teach N(T) classes.

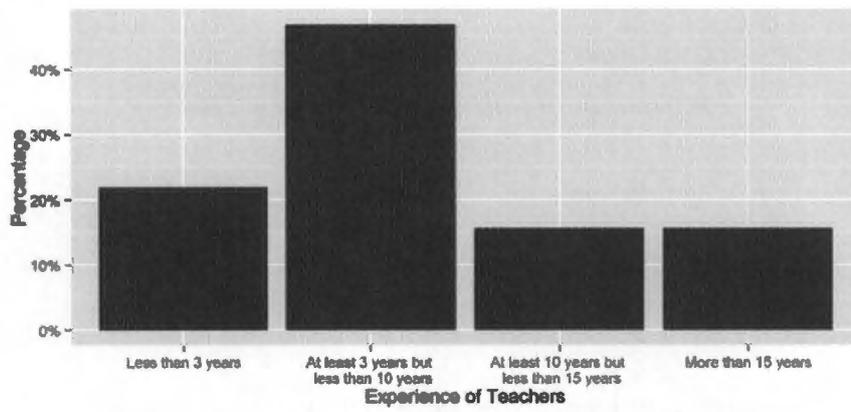


Figure 3 - Participants' teaching experience

## Results

*Differences in beliefs about argumentation**Between activities requiring different levels of argumentation*

The summary of results (Figure 4 on the next page) reveals that most of the average effectiveness scores for N(T) are between 3-4 points (out of 6), with peaks at levels 0d and 1a. For Express, most of the averages are between 4.5-5 points, meaning that on average, the scores for effectiveness for N(T) are 1-1.5 points below that for Express. In considering the inter-resource range, with the standard error taken into consideration, there is really hardly any difference between argumentation levels for the perceived effectiveness of the argumentation resource for Express. However, there are significant differences for N(T), with a clear preference at levels 0d and 1a.

This clear preference is also reflected in teachers' likelihood in using the resources, with those at level 0d and 1a also being the most likely.

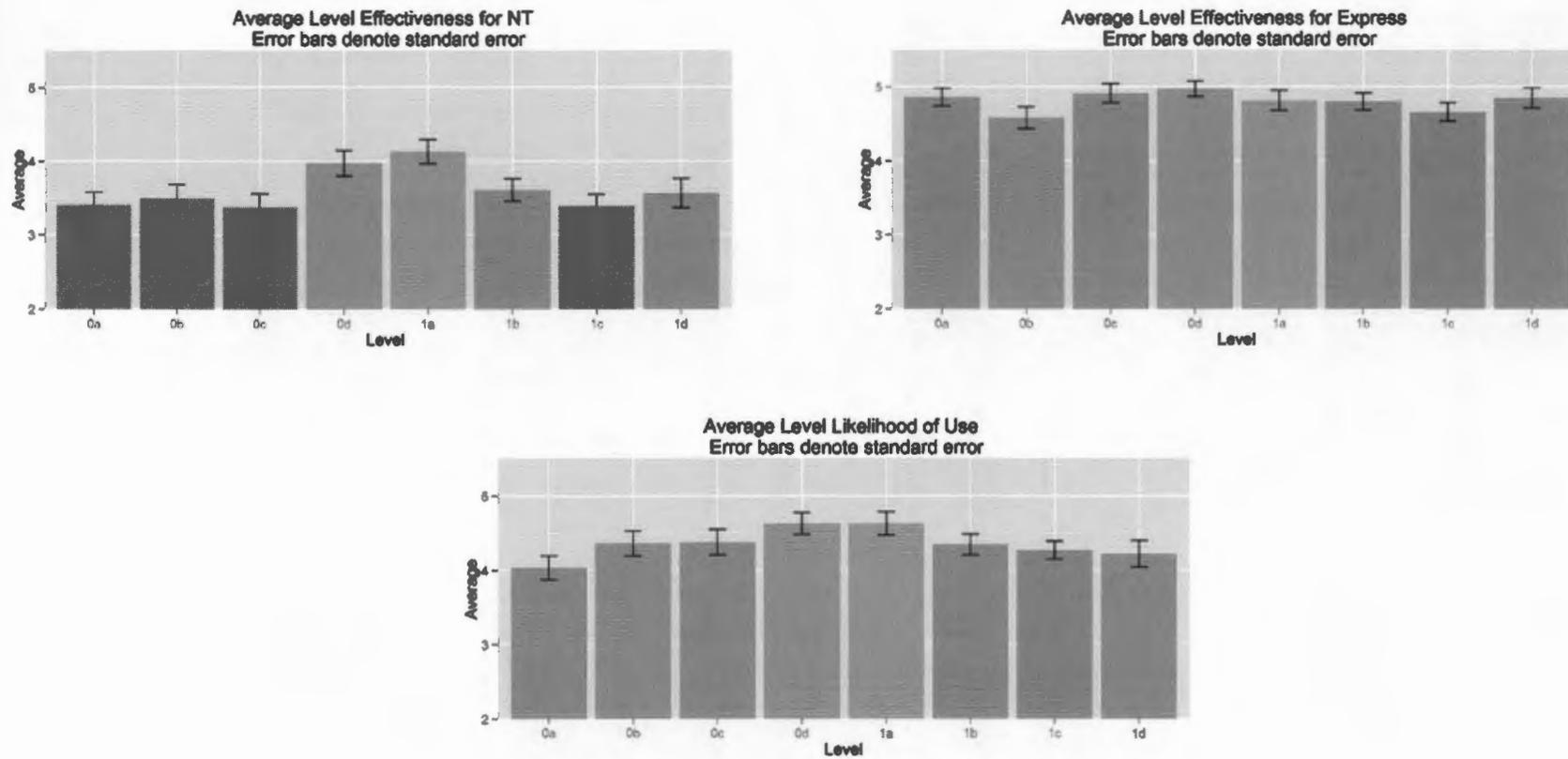


Figure 4 - Participants' average perception of effectiveness and likelihood of use, summarized across argumentation levels

*Between activities based on different topics*

In parallel to the difference in perceptions between N(T) and Express for argumentation level, the average topic effectiveness for Express is about 1 point higher than for that of N(T). The first two graphs of Figure 5 on the next page show that for both N(T) and Express, the physical science topics (Electricity and Forces) are deemed as more effective, and the third graph shows that the questions in these two topics are slightly more likely to be used if provided, compared to the biological science topic (Digestion).

*Between activities based on different question formats*

As per preceding sections, the average question format effectiveness for N(T) is about 1 point lower than that of Express. As shown in the first two graphs of Figure 6 on the next page, for both N(T) and Express, the “Table of Statements” format is perceived as slightly less effective than the others. The third graph shows that across all three question formats, the difference in perceived likelihood of use do not differ greatly – the range between all 3 is only 0.5 points.

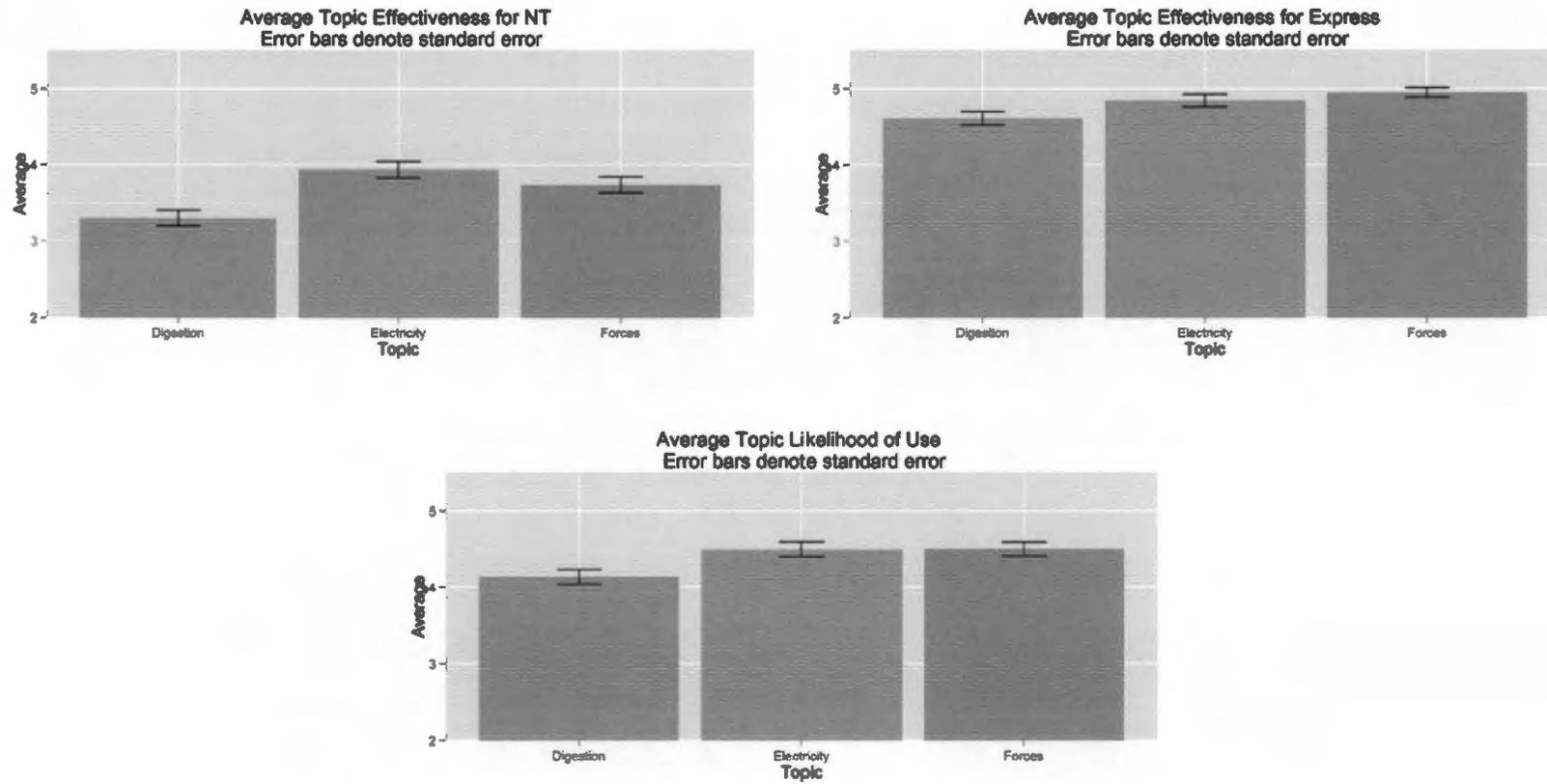


Figure 5 - Participants' average perception of effectiveness and likelihood of use, summarized across topics

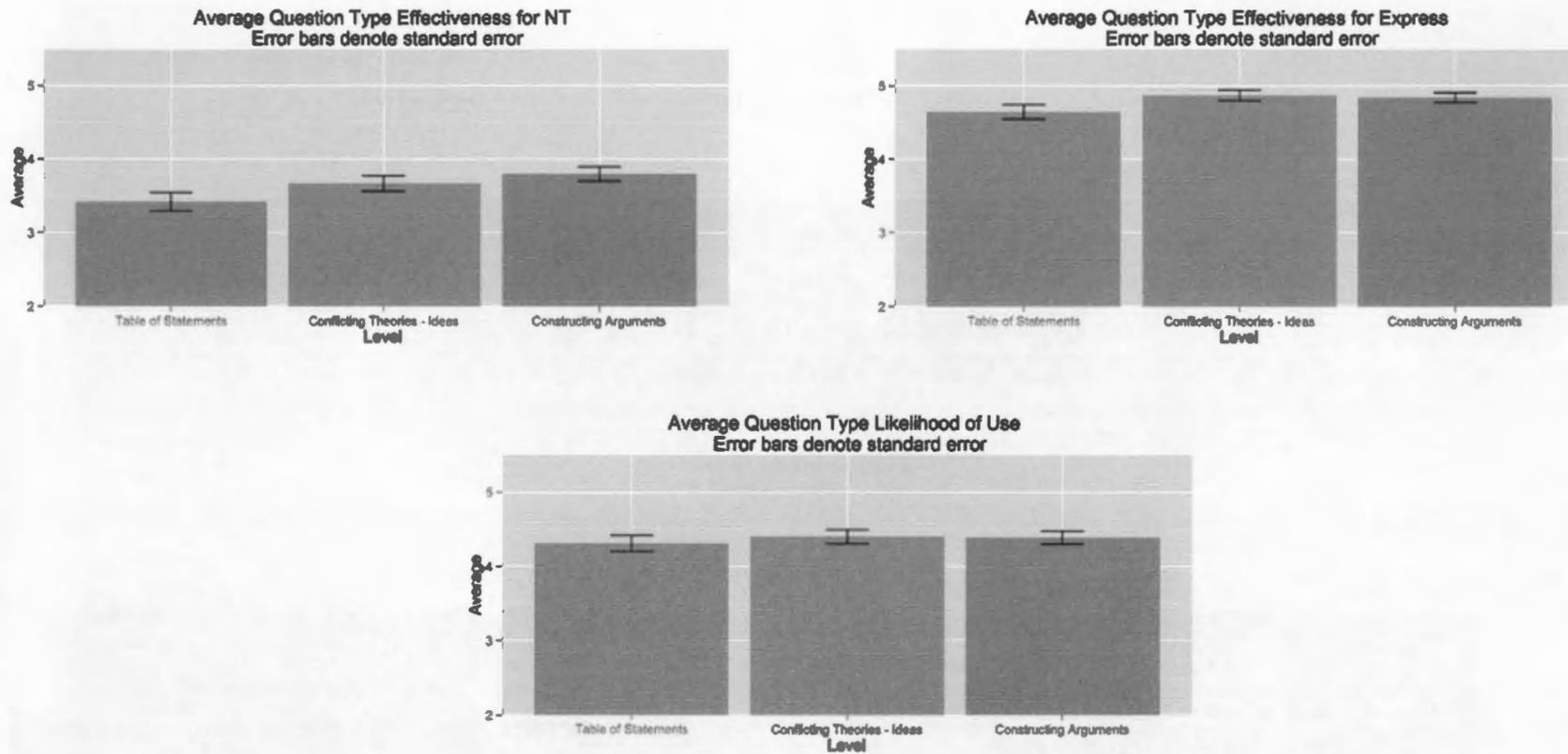


Figure 6 - Participants' average perception of effectiveness, ease of use and likelihood of use, summarized across question formats

*Teacher Pedagogical Practices and Preferences*

In general, the participants do not spend much time on CT activities in their N(T) classes. The majority of them spent less than 20% of class time on such activities, as seen in Figure 7 below. CT is in fact deemed as the least effective pedagogy, while Hands-On activities are seen as most effective (Figure 8 below), which collaborates with the common perception of N(T) students as hands-on learners (Ismail & Tan, 1997). It is also notable that strategies where students would not be required to interact with peers, such as seatwork and frontal instruction, were deemed more effective than those that require peer interaction.

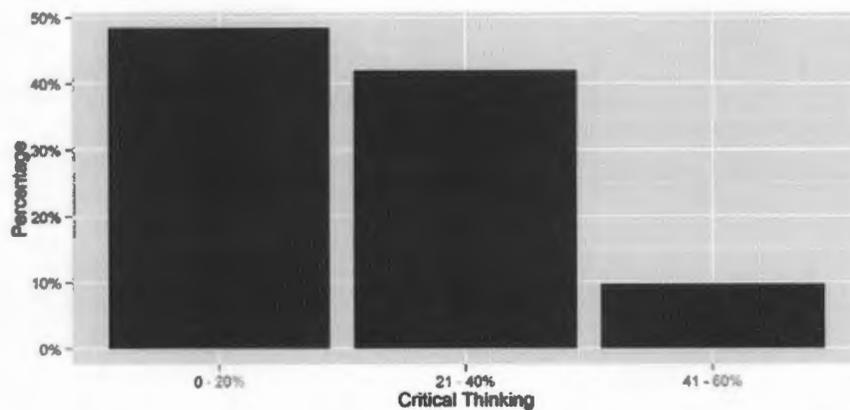


Figure 7 - Percentage of participants spending a specified proportion of their N(T) class time on critical thinking activities

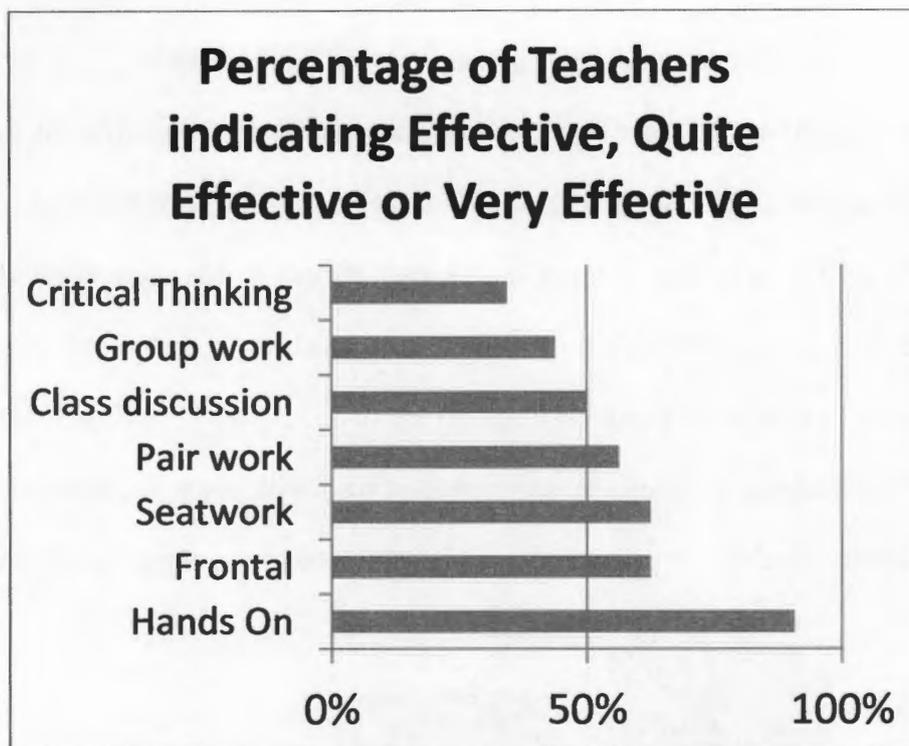


Figure 8 - Percentage of teachers indicating specific pedagogies as effective, quite effective or very effective for N(T)

*School-based factors*

*Satisfaction with Quality and Sufficiency of N(T) Resources*

*Quality*

Teachers were generally less than satisfied with the quality of available N(T) teaching resources, including books (textbooks, workbooks), handouts (notes and worksheets), and especially online resources, where half of teachers were not at all satisfied, as in Figure 9 below.

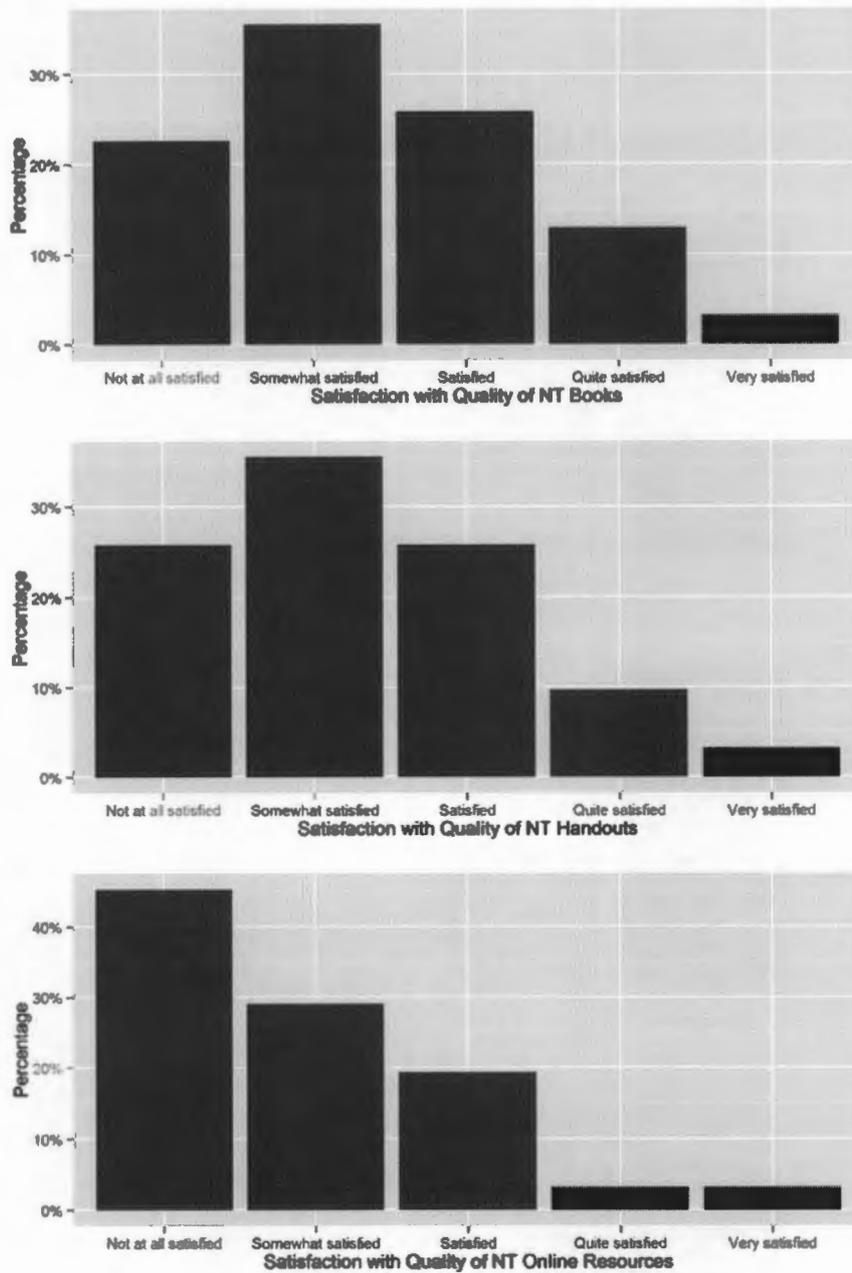


Figure 9 - Participants' satisfaction with the quality of available N(T) books, handouts and online resources

*Sufficiency*

Similarly, teachers were not satisfied with the sufficiency of books, handouts and online resources for N(T) – even less satisfied compared to the resources’ quality as above. The lowest, “Not at all satisfied”, was the modal response for all three types of resources, as seen in Figure 10 below. The relatively small proportion of N(T) students nationwide – less

than 15% - may possibly not be sufficient incentive for publishers and other commercial providers to develop sufficient, quality dedicated resources for them, and teachers may often have to rely on material developed for the other streams, such as Express.

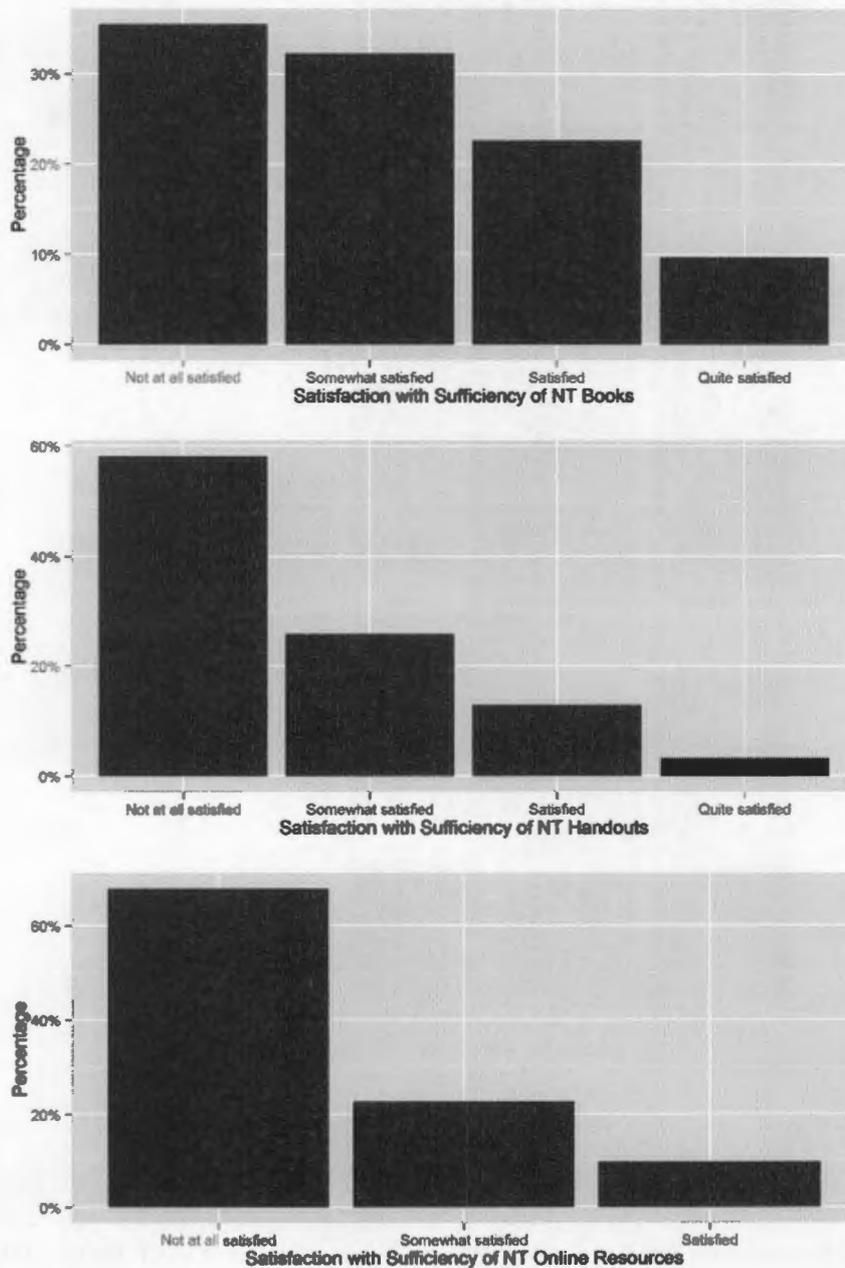


Figure 10 - Participants' satisfaction with the sufficiency of available N(T) books, handouts and online resources

Teacher- and school-related factors were tested using Pearson's Product against both effectiveness for N(T) and for Choice of Use, and a summary of the results is in Table 2

below. For each factor, the first row is the correlation with the perception of effectiveness for N(T), whereas the second is the likelihood of use.

Factor	95% Confidence Interval	R	p	Significance
<i>Teacher-related factors</i>				
<b>Teacher Experience</b>	0.271 < R < 0.759	0.562	0.0006635	***
	0.248 < R < 0.748	0.545	0.001052	**
<b>Leadership Status</b>	0.147 < R < 0.698	0.467	0.006201	**
	-0.125 < R < 0.530	0.228	0.2009	
<i>Class-related factors</i>				
<b>Rapport</b>	0.337 < R < 0.788	0.610	0.0001651	***
	0.347 < R < 0.792	0.617	0.000133	***
<b>Behavior</b>	0.259 < R < 0.753	0.553	0.0008421	***
	0.185 < R < 0.718	0.497	0.003248	**
<b>Critical Thinking N(T) Class Time Proportion</b>	0.377 < R < 0.805	0.638	6.504e-05	***
	0.378 < R < 0.805	0.638	6.39e-05	***
<i>School-related factors</i>				
<b>Satisfaction with Quality of N(T) Online Resources</b>	0.278 < R < 0.762	0.567	0.0005734	***
	0.239 < R < 0.744	0.538	0.001236	**
<b>Satisfaction with Sufficiency of N(T) Books</b>	0.037 < R < 0.637	0.376	0.03109	*
	0.164 < R < 0.707	0.480	0.004661	**
<b>Satisfaction with Sufficiency of N(T) Handouts</b>	0.198 < R < 0.724	0.507	0.002612	**
	0.204 < R < 0.727	0.511	0.002355	**
<b>Satisfaction with Sufficiency of N(T) Online Resources</b>	0.250 < R < 0.749	0.546	0.00101	**
	0.244 < R < 0.746	0.542	0.001135	**
<b>Satisfaction with availability of time to complete instruction of required N(T) topics</b>	-0.068 < R < 0.570	0.282	0.1119	
	0.331 < R < 0.786	0.606	0.0001885	***

Table 2 - Summary of correlations between teacher-, class- and school-related factors and perceptions of effectiveness for N(T) / likelihood of use (\* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001)

The table above shows that many teacher-, class- and school-based factors are related to teachers' beliefs about argumentation. In particular, rapport is closely correlated with both perception of effectiveness for N(T) and the likelihood of use. Teachers with stronger rapport with their N(T) students or perceived that their students' behavior were more likely to

perceive the resources as effective for N(T) and be more likely to use them. In the same vein, teachers that were more satisfied with either quality or sufficiency of resources (books, handouts, online resources) for N(T) were also likely to perceive the argumentation resources as effective and be likely to use them.

### Discussion

At first glance, the findings of teachers' beliefs for Express versus N(T) may parallel those recorded by Zohar and Dori (2003), where nearly half of interviewed teachers found high-CT activities inappropriate for low-advantage learners, and this fact was attributed to the "advantage effect" (Raudenbush, Rowan, & Cheong, 1993). Indeed, participants in this study reported both a low proportion of N(T) class time spent on CT activities in their science classrooms and the lowest preference among the different pedagogies for CT in N(T) teaching. Their CT practices and beliefs could be indicative of a rigor gap between Express and N(T) (Torff, 2008, p. 30). But even if it is given that teachers object *generally* to argumentation and CT as pedagogies for N(T), what do they *specifically* object to? An important objective of this research is to go beyond generalizations and dig into specific details of curriculum, because that is where the controversy over rigor is being played out.

Regardless of whether teachers' responses are partitioned by argumentation level, topic and question format, the difference between perceptions of Express versus N(T) is significant. This could well signify the operation of the "advantage effect". The preference for physical sciences may possibly be attributed to other factors such as a high number of engineering-background teachers and higher numbers of male teachers in this survey. The lack of significant changes in response as the argumentation progression map is climbed also bears mention. Given that increasing level signifies increasing cognitive demand, shouldn't there be a clear (inverse) relationship between level and effectiveness? There seems to be a

“sweet spot” of level 0d and 1a for N(T) but that was about all – whereas it appears flat for Express. Why 0d and 1a? Looking at comments given by survey participants for each resource reveals nothing about the nature of argumentation at those levels, and this may support the reasonable assertion that in reality, teachers evaluate resources holistically–based on content, interest, difficulty - and make dynamic adjustments to help their students learn. They could adapt their teaching strategies to the level of difficulty presented. For example, teachers commented that the level 1b electricity resource lent itself well to being taught through lab experiences, although it was a seemingly a question with a higher cognitive demand. If this is true of our teachers, then there is no justification for limiting argumentation to lower levels for lower-ability students.

Even more significant, though, is the fact that the difference is not substantial – 1 point out of 6 on average. The conclusion is promising: despite the evidence for belief in the advantage effect among the participants, if teachers find the resources effective and likely to be used for Express, they will on average find the same resources somewhat effective and somewhat likely to be used for N(T), despite the students being on the other end of academic spectrum. It is then left to find the *specific* objections that may be overcome for N(T). There is concern with argumentation-related nomenclature such as “claim”, “evidence” and “warrant”, as evidenced by responses on, for example, Resource 3, a question requiring students to identify the claims in a paragraph. Teachers on overall did not regard highly activities centered on the identifying of claims. But argumentation takes many forms. Interestingly, in participants’ comments about the other argumentation resources, “argument” or its derivatives was not mentioned, even though the participants were clear that the study was about argumentation. “Thinking” and “discussion” were mentioned a few times. Much more prevalent were comments about demonstrations (in Resource 5 and 11), visuals (e.g. Resource 9), and relevance to past experience and “real life” (e.g. Resource 2). These may be

teachers' pedagogical concerns today, and can argumentation not be introduced in a way that contributes to addressing these concerns, as what these teachers seem to think the research resources were about?

The finding of experienced teachers' greater perception of N(T) resource effectiveness and likelihood of use of argumentation resources, compared to less experienced teachers, parallels previous findings about expert teachers' preference for CT activities (Torff, 2006, p. 46), as experienced teachers have mastered a repertoire of strategies and are less likely to rely on a transmission style of teaching. Participants with leadership status may also perceive argumentation activities as more effective for comparable reasons. However, there might be other factors, not studied in this research, why leadership makes no difference in the likelihood of use.

More explicable is the close correlation of the proportion of CT class time with both perception of effectiveness and likelihood of use of argumentation. If the proportion of CT class time is taken as a reflection of teachers' disposition to use CT, then this effect is similar to others' findings that CT dispositions are linked to the likelihood of using CT (Facione, Sánchez, Facione, & Gainen, 1995). Thus, if CT is the teachers' least preferred pedagogy for N(T), then it is not surprising that a majority of teachers spend only 20% or less of their N(T) class time on CT.

It is remarkable that in the consideration of these curriculum resources, the class- and school-based factors actually exert a large effect on perception of effectiveness and likelihood of use. Better rapport with students, itself likely correlated with better behavior of students, correlates with effectiveness and likelihood of use – teachers feel freer to try new things with students within a culture of mutual trust and respect. Previous studies (Ismail & Tan, 1997) have flagged behavior as an ongoing concern that is reflected in these teachers' modal response -- nearly 50% of this study's participating teachers rate their students only 2/5 for

behavior. In addition, while satisfaction with the sufficiency and quality of resources has been shown to be important (Zohar, 2013) and correlated with the perception of effectiveness of resources and likelihood of use in our case, the startling fact is that these teachers are not at all satisfied with what they have on their hands to teach and engage their N(T) students. Time seems to be a factor strongly related to the likelihood of choosing a resource – a teacher hard-pressed for time would be less likely to choose the resource, regardless of how effective it was, based on comments on some of the resources:

*“It will take more time for the teacher to explain what is Claim and they will need to practise on a few cases before they can have a good understanding.”*

*“[The N(T) students] prefer direct instruction and get it over and done with doing any work, including thinking or discussion.”*

### Conclusion

Taken together, the results in the preceding sections suggest that while we do not lay claim to establishing causality at this initial stage of research, it is evident that addressing teachers' beliefs about argumentation entails not merely the tweaking of levels, topics and formats, but the holistic consideration of teacher-, class- and school-based factors.

#### *What the results suggest*

Our results may suggest that contrary to a common perception where young teachers are likely to adopt new ideas the easiest, when it comes to implementing argumentation in N(T), it is the experienced teachers that are more likely to successfully spearhead the way.

Our results also suggest that it is important to foster conditions of rapport and positive class behavior, and build teacher-student relationships that may promote implementation of argumentation. At the same time, effort could be invested in tandem in changing the mindsets

of teachers towards CT in general, and encouraging teachers to use more CT in their N(T) classes.

The results also demonstrate that on the ground, there may currently be room for improvement in the provision of quality N(T) resources (books, online resources, handouts). Such provision, alongside provision of argumentation-based teaching resources, would likely facilitate the implementation of argumentation.

*Final word*

While further research would certainly be required to strengthen the results from this initial study, the results do indicate cautious optimism for implementing argumentation in Singapore classrooms – even N(T) classrooms. Our participant teachers, despite not having exposure to argumentation pedagogy and despite having opined that CT activities are least effective for N(T) students, do not on the whole object to using these argumentation resources for either Express or N(T) students. Instead, they have demonstrated willingness to adapt these resources in light of their students' interests and abilities, drawing on strategies such as demonstrations to make these relevant to their students' lives. And if these dispositions are reflective of our science educators in general, be they N(T) teachers or otherwise, then the argument for argumentation in Singapore science teaching grows stronger by the day.

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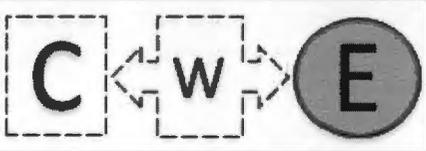
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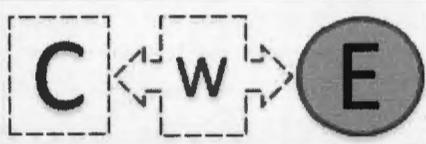
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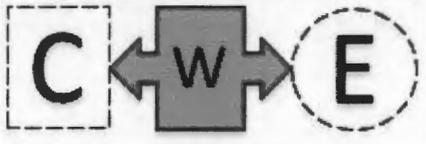
Appendix 1: A Progress Map for Argumentation/Scientific Reasoning

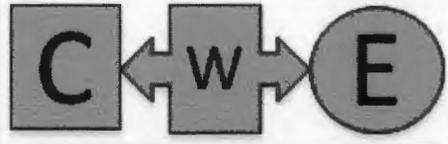
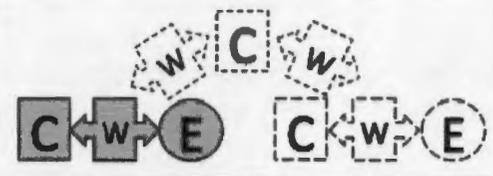
Osborne, Henderson, MacPherson, Szu, & Wild, Jan 2014

Level	Constructing Arguments	Critiquing Arguments	Description	Cognitive Load
0			<p>No explicit evidence of any facility with argumentation. Consideration of any of the core elements of argument (e.g., claims, warrants, and evidence) evidence is implicit at this bottom anchor of the progress map.</p>	 <p>Any cognitive consideration of any of the core elements of argument remains implicit, if it exists at all.</p>
0a	<p><b>Providing a relevant claim</b></p>		<p>The most basic demonstration of argumentation competency, as providing a claim relevant to the context of a question does not technically require any additional knowledge of the features of an argument. Indeed, it is possible for a student to construct a claim without actually knowing what it means for a statement to function as a claim in an argument. It is impossible to engage in argumentation without a knowledge of the claim(s) that is (are) in contention, and hence this marks an early stage of the progress map.</p>	 <p>Only a single core element of argument – the <i>claim</i> – needs to be made explicit. An explicit construction of a claim can be done without any implicit consideration of how a</p>

				claim actually functions in an argument, let alone how warrants and evidence function.
0b		<b>Identifying a relevant claim</b>	<p>This progress level is marked by the capability of a student to <b>identify</b> the tentative component of an argument that requires justification – the <i>claim</i>.</p> <p>As opposed to simply advancing a claim that may or may not be true (i.e., Level 0b), now a student must tease out a claim from other argument features (e.g., warrants and evidence).</p>	 <p>Only a single core element of argument – the <i>claim</i> – needs to be made explicit, but to tease this claim out of an argument, other features of that argument need to be considered implicitly.</p>
0c	<b>Providing evidence supporting a relevant claim</b>		<p>This progress level is marked by the capability of a student to explicitly identify a piece of evidence that supports a claim they have provided.</p> <p>While items probing this level only explicitly ask for a supporting piece of evidence to be identified, one cannot simply say something is</p>	 <p>Only a single core element of argument – a piece of <i>evidence</i> – needs to be made explicit, but to tease this evidence out of an</p>

			<p>“supporting” without a referent as to what is being supported. Hence both claim and warrant need to at least be implicitly considered when identifying a piece of evidence as “supporting.”</p>	<p>argument, other features of that argument need to be considered implicitly.</p>
<p>0d (not in prior map)</p>		<p><b>Identifying evidence supporting a relevant claim</b></p>	<p>This progress level is marked by the capability of a student to explicitly identify evidence which supports a claim that is not their own.</p> <p>As opposed to Level 0c, here a student may need to identify a piece of evidence that supports a claim they <u>might not necessarily agree with</u> (e.g., their content knowledge suggests otherwise).</p> <p>Note that the claim would need to be identified first, hence progression to this level entails mastery of Level 0b first.</p>	 <p>Only a single core element of argument – a piece of <i>evidence</i> – needs to be made explicit, but to tease this evidence out of an argument, other features of that argument need to at least be considered implicitly.</p>

Level	Constructing Arguments	Critiquing Arguments	Description	Cognitive Load
1a	<p><b>Providing a valid reason that links evidence to a relevant claim</b></p>		<p>Items that require explication of warrants mark the transition from Level 0 to Level 1 on our progress map. This builds on previous levels of the progress map as it requires understanding of not only what constitutes a claim or a piece of evidence, but also how to coordinate a relationship between claim and evidence.</p> <p>These intermediate levels are prefixed with the number one to denote <i>one degree of coordination</i> – i.e., students need to coordinate one explicit logical connection between claim and evidence by way of a warrant.</p> <p>Only the warrant is made explicit at this progress level.</p>	 <p>Students need to coordinate one explicit logical <u>connection</u> between claim and evidence by way of a warrant. At this level only the warrant is made explicit, but as the function of the warrant is to connect claim with evidence, such claim and evidence must be implicitly considered.</p>
1b (not in prior map)		<p><b>Identifying a valid reason that links evidence to a relevant claim</b></p>	<p>As opposed to Level 1a, this progress level is marked by the ability to identify a relationship between claim and evidence, <u>even if the student does not necessarily agree with that reasoning.</u></p> <p>As with Level 1a, items probing this level only ask for students to explicate the warrant.</p>	 <p>Students need to coordinate one explicit logical <u>connection</u> between claim and evidence by way of a warrant. At this level only the warrant is made explicit, but as the function of the warrant</p>

				is to connect claim with evidence, such claim and evidence must be implicitly considered.
1c (formerly 1b)	<b>Providing an explicit argument in the affirmative</b>		<p>This progress level is marked by the capability of a student to make a claim, select evidence that might support that claim, and then construct a synthesis between the claim and the warrant.</p> <p>At this level both the claim and evidence are also made explicit in addition to the warrant, whereas only the warrant is explicated in Levels 1a and 1b.</p>	 <p>Students need to coordinate one explicit logical <u>connection</u> between claim and evidence by way of a warrant. At this level the claim and evidence must also be explicated in addition to the warrant.</p>
1d (not in prior map)	<b>Providing an alternative counter argument</b>		<p>This progress level is marked by the student capability to explicate a complete argument that runs counter to an argument they find less satisfactory. Items probing this level only require a student to make the counter argument explicit.</p>	 <p>Students need to coordinate one explicit logical <u>connection</u> between claim and evidence by way of a warrant. At this level the claim and evidence must also be explicated in addition to the warrant. Furthermore, as the argument is offered as a counter to another argument, some elements of that argument are likely to be considered implicitly. A rationale for why the counter argument is superior may also be considered implicitly.</p>