Proceedings of the Nineteenth Annual Meeting of the

SAARMSTE

SOUTHERN AFRICAN ASSOCIATION FOR RESEARCH IN MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION (SAARMSTE)

Mathematics, Science & Technology Education – A bridge to the future

18 - 21 JANUARY 2011

Hosted by the North-West University- Mafikeng Campus

Long Papers

Edited by Thapelo Mamiala and Frederick Kwayisi

2011 North-West University- Mafikeng Campus, Republic of South Africa

ISBN # 978-0-9869800-0-8

SAARMSTE COMMITTEES 2011

SAARMSTE EXECUTIVE COMMITTEE

President:	Prof Marc Schäfer (Rhodes University)
Past President:	Mr Chipo Fumhanda (New Zealand)
Secretary – Treasurer:	Prof Marie Botha (University of Pretoria)
Regional Representatives:	Dr Emilia Afonso -Mozambique Chapter (Universidade Pedagogica)
	Prof. Helen Drummond – North West Chapter (North-West University)
Research Capacity Rep:	Dr Tulsi Morar (Nelson Mandela Metropolitan University)
AJRMSTE Editor:	Prof Fred Lubben (CPUT & University of York)
Secretariat (ex-officio):	Ms Caryn McNamara (Rhodes University)

SAARMSTE LOCAL ORGANISING COMMITTEE (LOC) 2011

Chairperson:	Prof Thapelo Mamiala (North-West University)
Treasurer:	Prof Helen Drummond (North-West University)
Secretary:	Dr Jacob Tholo (North West Department of Education)
Organiser:	Dr Frederick Kwayisi (North-West University)
Members:	Ms Sophy Mangope (North West Department of Education)
	Ms Helen Thomas (North-West University)
	Ms G Poti (North West Department of Education)
	Mr Noorullah Shaikhnag (North-West University)
	Ms V Leketi (North West Department of Education)
	Mr Andrew Mutsvangwa (North-West University)
	Mr Nkosana Mavuso (North-West University)

SAARMSTE PROGRAMME COMMITTEE 2011

Programme Chair:	Dr Frederick Kwayisi (North-West University)
Proceedings Editors:	Ms Helen Thomas (North-West University)
	Prof Thapelo Mamiala (North-West University)
Mathematics Coordinator:	Prof Thapelo Mamiala (North-West University)
Science Coordinator:	Prof Helen Drummond (North-West University)
Technology:	Dr G.M.Reitsma (North-West University)
Members:	Dr Jacob Tholo (North West Department of Education)
	Ms Sophy Mangope (North West Department of Education)
	Ms Brenda Mokotedi (North West Department of Education)
	Mr K. Maletsoa (North West Department of Education)

Effects of dialogical argumentation-based workshops on primary and secondary school teachers' ability to co-construct the concept of solubility

Samuel Kwofie [1] **Meshach Ogunniyi** [2]

[1] *South African National Bioinformatics Institute.* [2] *School of Science and Mathematics Education, University of the Western Cape, South Africa.*

[1] samuel@sanbi.ac.za, [2] mogunniyi@uwc.ac.za

Abstract

This article presents a case for equipping science teachers with the necessary skills needed to enact dialogical argumentation-based classroom discourses. Even though teachers are required to scaffold knowledge construction in the classroom, it appears that not much prominence has been dedicated to exploring alternative or novel approaches to teaching. Hence, this research seeks to evaluate the effectiveness of dialogical argumentation-based pedagogic framework as essential tools for enhancing teachers' ability to co-construct solubility concepts in the classroom. The workshop sessions employed for this study involved primary and secondary school teachers. The results reinforces the belief that dialogical argumentation-based model is a plausible pedagogic approach which augments teachers' ability to co-construct scientific knowledge and also improves their quality of argument during discursive classroom environment. In addition, frequent epistemic interactions during dialogue could enable the teachers to synthesis and critically evaluate scientific concepts as well as exhibiting keen interest in problem solving discourses.

Introduction

It is a well known fact that science teachers' conceptions of the Nature of Science (NOS) are anything but adequate (e.g. Arkerson & Abd-El-Khalick, 2003; Schwartz, Lederman & Crawford, 2004). In this regard, teachers tend to present scientific knowledge as a ready-made product to be transmitted verbatim to students without making any serious attempt to reveal the heated debates and controversies involved in generating such knowledge. As Ziman (2000) has succinctly put it, "Scientific biographies are deeply scarred by private episodes of vitriolic personal jealousy between individuals…The frontiers of knowledge are partitioned into a thousand special territories" (p.29). Kittleson and Southerland (2004) add that in order to understand how scientific knowledge is constructed one needs to know how that knowledge "is negotiated or co-constructed in social settings" (p. 268).

Co-construction of knowledge is a joint and collective endeavour undertaken to build an understanding of a given phenomenon. It is a collaborative experience shared by a group of people in the act of performing a task. Although much has been revealed in the last few decades about the nature of contestations and vibrant social interactions among scientists in the process of knowledge construction through the works of Popper, Kuhn, Hempel, Lakatos, Merton and others, not much has been done to help science teachers reflect that critical aspect of the Nature of Science (NOS) in their classrooms. Also, not much has been done to examine the effectiveness or otherwise of teachers' pedagogic training programmes aimed at equipping them with necessary knowledge and pedagogic skills to facilitate meaningful discourses in their classrooms (e.g. Driver et al, 2000; Kittleson & Southerland, 2004). Hence, this study aims at contributing towards efforts made to fill this gap. It is an attempt to train a group of teachers on how to make co-construction of knowledge an important aspect of their instructional practice. The new South African curriculum emphasizes the need for students to develop critical process skills. However the same curriculum does not explicitly state how such skills can be developed among students.

Theoretical Framework

Argumentation is a statement advanced to justify or refute a claim in order to attain the approbation of an audience (Van Eemeren, et al, 1987). Argumentation has been used as a rhetorical and instructional tool since time immemorial. It was a common rhetorical tool used by pre-Socratic natural philosophers before 500 BC as well as by succeeding generations of scholars up to the present day scientists in their attempts to unravel the nature of matter and the universe as a whole (Popper, 2001). As Fraser, et al (1994) have contended, 20th century physics (using arguments and counter arguments backed by scientific evidence) depict two major voyages in science of discovery namely, looking "outwards through telescopes toward the edge of the universe" and probing the micro-cosmos, namely, "the minuscule world of atoms and sub-atomic particles" (p.13). The underlying assumption of the study therefore was that training teachers explicitly on how to co-construct concepts (like scientists do) might be an effective way to develop process skills among their students. It was for the same reason that argumentation was used as the organizing framework for the development of Argumentation-Based (A-B) workshops discussed later in the paper.

An argumentation model that has featured prominently in the science education literature in recent years has been Toulmin's (1958) Argumentation Pattern (TAP). The TAP consists of: a claim or an assertion, a declarative statement or belief about a given phenomenon; data or evidential or supportive statements of that assertion; warrants or statements which seek to justify or show a relationship between the data and the claim; backings or implicit assumptions of the claim; qualifier or the contingent conditions on which the claim is based; and rebuttals or contrary statements to the claims. Some criticisms that have been levelled against the TAP include: the inconsistent way in which it presents the validity of an argument; its use in certain cases of formal logical meaning of "soundness" and so on (Van Eemeren, et al, 1987). However, despite the criticisms that been levelled against TAP, its great contribution lies perhaps in its rejection of a universally applicable argumentation model as well as serving as a useful guide in assessing arguments in a given context. For instance, a number of studies have shown that there is no common pattern in the way teachers use even the same form of arguments in their classrooms. In other words, the use of arguments appears to be teacher dependent (Erduran, Simon & Osborne, 2004). To avoid the usual overlaps among the elements of the TAP this study has adopted a modified version of the TAP by considering data, warrants and backing simply as grounds (Erduran, Simon and Osborne, 2004). It is this modified version of TAP that we have used in the analysis of data collected in the study.

Purpose of the Study

The aim of the study was to examine the effect of Dialogical Argumentation Instructional Model (DAIM) on teachers' understanding of selected science concepts. The DAIM was used as exemplary model of instruction which science teachers could use to facilitate the co-construction of science concepts with their learners. We also chose the approach to provide the needed intellectual space for teachers and and consequently their students to discuss and argue more freely in the classroom. We also hoped that unlike the typical teacher-centred approach (where teachers tend to dominate classroom discussions), the approach we have adopted would enable students to clear their doubts, revise their conceptions and even change their attitudes as a result of listening to the views of others (Erduran, Simon & Osborne, 2004; Ogunniyi, 2006, 2007 a & b). More specifically, the study sought to determine possible effects of an activity-based DAIM in enhancing the concept of solubility among a cohort of teachers who attended a series of workshops for a period of six months. In pursuance of this aim we sought answers to the following questions:

1. How effective is the DAIM in enhancing the teachers' ability to co-construct with their peers the concept of solubility?
2. What levels of the TAP are evident in the teachers' dialogic argumentation as they work on solubility of two unknown substances?

The questions above imply that the teachers who participated in the workshops performed the solubility task first as individuals, then in a small group and finally as a whole class. The different forms of conversations occurring at the various levels (individual, group and class) are what we designate as "intra", "inter" and "trans" dialogical argumentation-all forming a critical part of scientific inquiry. The underlying assumption here is that there is a world of difference between solving a problem e.g. performing a cognitive task individually or an investigation and doing so within a small or large group entailing the whole class. Two related assumptions in this regard are: (1) teaching or learning a concept through the transmission mode is quite different from doing the same in a small or large group with an ample opportunity for dialogue; and (2) carrying out actual experiments on the unknown substances would enable the teachers to have first-hand experience of the struggles and the difficulties that their students are likely to encounter while performing the solubility task.

Method

Dialogical Argumentation Instructional Model

The main study involved 13 primary and secondary science teachers with varied content and pedagogic content knowledge, an issue not presented for lack of space in this proposal. The teachers attended three-hour per week workshops underpinned by TAP for a period of six months. In addition, they were assigned selected readings based on the works of well known scientists, philosophers, historians and sociologists of science (e. g. Ziman, Medawar, Popper, Hempel, Kuhn, Merton) on the one hand and science educators on the other (e.g. Driver, Abd-El-Khalick, McComas, Lederman and others) with respect to the socio-cultural dynamics existing within the scientific community (e.g. see Ogunniyi, 2007 a & b). The first session began with a brief lecture on the fascinating story of what Hungarian physician Semmelweis did to find out the cause(s) of childbed fever. They were also introduced to the controversies that ensued among pre-Socratic philosophers (about 500 B.C.) and scientists in the early 20th century regarding the nature of the atom as lucidly espoused in a book titled, "The Search for Infinity" (Fraser, Lilellotstol & Sellevag, 1994). The purpose of the reading assignments was to create the teachers' awareness about how scientists go about constructing knowledge in their various fields and to show how to reflect same in their instructional practices. As an example we provide an abridged version of one of the workshops on the Nature of Science (NOS) as follows:

Workshop 1 on the Nature of Science

These workshops will introduce you to various aspects of the Nature of Science (NOS). You will learn about the scientific assumptions, hypotheses, laws, theories and the type of reasoning used in science such as: deduction, induction, and practical reasoning and so on. Specifically, you will learn about a form of argument proposed by a British philosopher called Toulmin. Toulmin (1958) proposed an argumentation model popularly known as the Toulmin Argumentation Pattern (PAT). It consists of six elements i.e. a claim, evidence (data), warrant, backing and rebuttals. The excerpt below is derived from the content of one of the workshops to which the teachers were exposed:

> A good example that we shall consider in today's workshop is the historical case of Ignaz Semmelweis and his research team. Ignaz Semmelweis was a Hungarian doctor who between 1844 and 1848 attempted to find out the causes of childbed fever which resulted in the deaths of several women who came to deliver their babies at a particular hospital and so on (see the full story in the Appendix 1). As scientists normally do Semmelweis proposed a number of

hypotheses (a wise and informed guess) to find the cause(s) of childbed fever. Despite several trial experiments carried out to test the validity of these hypothesis he found to his dismay that nothing seem to change as the women continued to die! In other words, the results of his experiments did not provide solid valid evidence (data) or warrant (justification) for the claim implied by the hypotheses. He resolved to make more careful observations to obtain more reliable evidence. But despite his effort, the women continued to die at child birth. He had no option than to revise his hypotheses until the causes of the disease were known… In your groups you are expected to discuss and argue about Ignaz Semmelweis and his research team went about co-constructing knowledge until they resolved the mystery surrounding child-bed fever. But in your discussion remember the emphasis is not to win an argument but to reach consensus on the basis of solid and justifiable claim.

Wrap-up questions:
The two wrap-up questions for this morning session which you need to work upon in your take home assignment for the next workshop are**:**

1. Based on the story of Semmelweis, what have you learned about the NOS? "What role does a hypothesis play in a scientific investigation?" Based on the story of Semmelweis, what have you learned about the NOS?
2. What role does a hypothesis or theory play in scientific investigation?

Assignment 1:

(a) You are to submit 1-3 page reflective essay on what you have learnt about the NOS in the first workshop (please cite relevant references) and how this would impart your instructional practice.

(b) To benefit from the workshops it is critical to read handouts provided on the NOS.

(c) Select a partner with whom you would debate a topic from the list below in the next workshop…

The workshops on Solubility

The solubility tasks were carried out by four groups of participating teachers in two separate workshop sessions. The first session consisting of activities 1 and 2 asked the teachers to examine the materials on their tables and then to perform experiments that would help them identify the two unknown substances on their tables. As indicated earlier, DAIM based-activities involved the specification of the intended outcomes, the materials to perform the tasks and following the protocols which entailed: individual brainstorming i.e. a form of self-conversation or "intra-dialogical argumentation level," group or inter-dialogical argumentation and whole class or "trans-dialogical argumentation." For example activity 1 involved the following:

Intended outcomes: Solubility of solutes in solutions depends on the relationship between their chemical and physical properties and these are affected by: temperature; polar or non-polar properties; intra and inter molecular forces; likeness (polar dissolves in polar and non polar dissolves in non polar); amount of solutes in solution (saturated, unsaturated and supersaturated); acidity or alkalinity; crystal size of solutes and so on. Next was the sequence of activities: **prediction; argumentation and dialogues; experimentation; observation; and reinforcement and consolidation of knowledge** at the intra-, inter- and trans- dialogical argumentation levels. The two unknown substances were: distilled water (substance A) and 20g sodium acetate (substance B). The apparatuses included: 300/250 ml beaker; hot plate; water bath; conical flask; stirring rods; small measuring cylinders; tongue holders; eye protection goggles; filter strip to test to test alkalinity; bottle stoppers; and funnels to dispense water. To make the investigation interesting as well as intensify the discussions certain material detractors were deliberately put among the items on the tables.

Methodology and activity worksheet for Activity A

Individual Task-You have been given the above apparatus and chemicals: 1. Brainstorm (intra-argument or self-conversation) and predict the types of experiments to be done. 2. State your predictions as your **claims.** 3. State your reasons as your **data or evidence.** 4. How did you arrive at your claims and evidence? 5. How can you justify your claims? 6. Is there a relationship between your claim and evidence? Yes or No. 7. If yes, then state these relationships as **warrants**. 8. Assumptions are part of scientific reasoning. What assumptions did you make in order to arrive at your predictions? State these as your **backings or grounds. 9.** By looking at the equipment and chemicals again, identify any extra conditions which may have aided you in making your claims. 10. Record these conditions governing your claims as **qualifiers.** 11. Remember that at the intra- argumentation level no one challenged or opposed your claims. What level(s) of argumentation did you deploy out of the seven levels of TAP (modified from the five espoused by Erduran, et al, 2004) in filling the worksheet? You are now ready for small group activities: level 1 consists of a non-oppositional claim; level 2 consists of a claim versus another claim or counter claim; level 3 consists of a claim/counter claim with evidence, warrants, a backing/qualifier or grounds but no rebuttal; 4. consists of a claim/counter claim with evidence, warrants, a backing/qualifier and at least one rebuttal and so on. The seventh level has an extended argument with two or more counter claims and rebuttals.

Small Groups Task- In order to justify your claim, discuss your arguments with other members of your group and then tabulate the arguments in terms: claims; evidence, warrants, and backings/qualifiers (grounds); and rebuttals. In terms of these elements of TAP, are there any competing or different claims to which the teachers were to express **Yes** on **No.** If yes, they would list these as **counter claims**. 2. If the claim was challenging other people's claims, then this must be provided as evidence. The evidence would be used to invalidate such claims. 3. If the evidence stated to support the dispute was valid then was regarded as the **rebuttal**. 4. By determining the various levels of argumentations the teachers might have used plus much reflection before some consensus was then reached. 5. They were also to state the experiments that they hade agreed upon or unanimously predicted. This experiment then served as the basis of their claims. 6. By stating the data, warrants and backing/qualifiers they might have used they were then ready for the whole class or trans-argumentation dialogues.

Whole class discussions: 1. The leader in each group would present their claims, evidence and warrants, backings/qualifiers to support their arguments. 2. Facilitators would then mediate whole class to identify counter claims and rebuttals. 3. The class agrees on the various levels of argumentations. 5. The class would reach a consensus on the type of experiment to be done.

In brief, activities 1 required the participating teachers to identify the two unknown substances on their tables. Activity 2 followed the same procedure on solubility tasks. The following workshop was used to complete activity 3. After the six-month workshops the teachers were introduced to DAIM through prototype lessons as exemplars. A lesson could be based on an inductive or deductive instructional model or hypothetical-deductive model of the NOS depending on the envisaged outcomes. This paper is based on the latter. The teacher were confronted with tasks without suggesting to them the topic other than to brainstorm individually (i.e. at the intra-argumentation level) and collectively (i.e. at the inter-argumentation level) the topic and experiment and then co-construct the appropriate concept(s) from a collection of materials on their lab tables. The task of the facilitator during in the first one and a half hour workshop sessions was mainly to facilitate collaborative dialogues among the teachers through thought-provoking questions. The next hour was used for group presentation followed by the whole class discussion and summary. The last 30 minutes of the session was used to identify collectively the levels of arguments used by the teachers. To reinforce their argumentation skills the teachers were then given some assignments for the next workshop. All the lab sessions were recorded using both audio-video- tapes. The transcribed materials were then analyzed in terms of qualitative descriptions. More details about the Dialogical-Argumentation Instructional Model (DAIM) used in the study have already been published (Ogunniyi, 2007a &b).

The NOS questionnaire consisting of 18 items was the outcome of a series of refinements of a 30-item earlier version based on scholarly critique and a pilot test involving 45 teachers. Validity checks involved average pair-wise ratings of items from 1 to 5 (1 being a poor item and 5, an excellent item) by four science educators on the final draft of the questionnaire. Using the Spearman Rank Difference formula, the correlation stood at 0.98 while an odd-even and a split-half correlation stood at 0.92 and 0.99 respectively. Likewise, the correlation of the categorizations of the teachers' levels arguments in a Lab session by two independent experts stood at 0.94 using the same formula. These indices show a strong face, content and construct validity of the instrument. Further details about the development of the questionnaire have already been published elsewhere (Ogunniyi, 2007a &b). The preliminary findings on a selected lab session are presented in the section that follows. Because of space limitations we shall place our emphasis on only the leaders of each group who acted as the "voices" of their respective groups. We shall also attempt to show to what extent Toulmin's Argumentation Pattern are manifested in the discussions of the groups and the whole class.

Results and Discussion

The preliminary results briefly summarized here are based on transcribed textual data extracted from the audio and video archives, and discursive worksheets designed for the purpose. The worksheet was designed in such a way to allow the enactment of the discourses in intra-, inter- and trans-argumentation-based scenarios. The main tasks required of the teachers were: (1) the identification of the unlabelled chemical substances based on their physicochemical properties and (2) the suggestion of plausible potential laboratory experiments using the provided substances and laboratory apparatus. The argumentation-based instructional model developed in this research has been shown to create a positive learning environment, which enabled teachers to actively participate in the workshop activities. The teachers exhibited keen interest and positive attitude towards the problem solving science based discourses. In most instances they relied on their prior experiences and knowledge which emerged during the argumentations. Most of the claims which they made (supported with grounds) pertained to physicochemical properties of substances. It emerged that DAIM is an effective pedagogic tool for enhancing teachers' ability to co-construct with their peers the concept of solubility. The teachers' conceptual understanding of scientific knowledge as a whole appeared to have been reinforced. Before arriving at claims, the teachers sometimes did not base their arguments on scientific phenomena pertaining to solubility alone but also integrated other relevant scientific concepts. It was evident that the teachers developed high level argumentation skills since there was an increase in the levels of argumentation during the DAIM discourse. A trend seemed to have emerged where increased epistemic interactions seemed to have led to higher incidences of rebuttals with the potential to augment their argumentation skills.

Evaluating the quality of argumentation

In seeking answers to our first research question we critically examined the obtained textual data for instances of dialogical argumentation in the discourses. In most instances the participants were able to support any inference made with grounds (see Erduran, et al, 2004) such as evidence, warrants, backings and qualifiers. Even though some of the grounds assigned may not be entirely scientifically reasonable or valid to some extent, these attempts buttressed the fact that the teachers interrogated and critically analyzed their scientific thoughts. Semantic evaluation of the textual data also showed that their discussions were characterized with the terminology "if" and "then" as would be found in the *modus tollens* of nomological deduction. This terminology could highlight instances of argumentation in textual data. High frequency occurrence of "if" could also correlate to enrichment of dialogical argumentation discourses. In this work, the frequent usage of words such words such as claims, warrants and qualifiers pinpoint teachers' conceptual understanding of DAIM. The results presented below are indicative of how the discourses were enriched with features pertaining to Toulmin's Argumentation Pattern (TAP).

Individual and intra-group discussions

Example 1 (Group 1)

T1 also the team leader of group 1, contended that, "If a substance boils at a certain temperature, the identity of the substance can be determined... assuming that the substance is pure." To posit his claim he first argued that knowing the physicochemical properties of substances was a way to identify the actual substances.

T2 on the other hand claimed that, "If an impurity B is added to A, the boiling point of A will increase." Although he did not explain why he thought B was an impurity he buttressed his claim by suggesting first to: "Determine the boiling point of A alone. Thereafter add B and determine the boiling point." He argued further that, "If the temperature of A is increased, the solubility of B in A will increase." To him, "If A and B are pure substances, their identities can be determined by finding their fixed points [fixed points could be boiling or melting points]."

T3 argues that, "If the temperature is increased, the solubility of B in A will increase. If the temperature is increased, the solubility is also increased."

Interestingly, while the focus of T1 was on identification of the unknown substances A (liquid) and B (solute), T2 was already hypothesizing that the task was concerned with determining the solubility of solute B in solvent A in different temperatures. T3 agreed with T1 and T2 regarding the effect of temperature on the solubility of substances. T1, T2 and T3 used physicochemical properties such as boiling points and physical appearances of the liquids and solids as grounds to buttress the espoused claims. By carefully linking the physicochemical properties of substances (evidence) to their claims, the group has thus established a relationship or warrant between the claim and the evidence. In summary, T1, T2 & T3 made a claim of identification of substances which was supported to certain extent with grounds. T2 went further to provide evidence for two extra counterclaims: (a) effects of impurities on the boiling point of liquids and (b) effect of temperature on solubility. By evaluating the above arguments in the context of TAP the individual/group's argument was primarily at level 2.

Example 2 (Group 2)

T4 also the team leader of group 2, predicted that the materials on the table were concerned with "an experiment on solubility, identifying types or classes of compounds" and that "substance B was salt." However, he was not sure if substance A was pure water because of its slight adhesion to the sides of the test tube. He supported his claims with the evidence that: substance B was in form of "white crystals shape … was colourless and odourless."

Like T4, T5 predicted that the experiment was concerned with testing the type of salt provided and whether B would dissolve in A. T4 & T5 went further by claiming that "B was NaCl [while] substance A could be water, acid, base or alkaline…flaky, damped, white and shiny in colour."

In summary, T4 & T5 made a claim of identification of substances which was supported to certain degree with grounds. T4 & T5 went further to provide some data for another counterclaim: solubility experiment. The teachers in group 2 like those in group 1 predicted reasonably the correct experiments and identified substances A and B basing their claims on physicochemical characteristics of A and B as evidence even before carrying out the experiment. In terms of the TAP their level of argument was also 2. With few exceptions the arguments used by groups 3 and 4 represented by T7-10 and T10-13 respectively were also at level 2 of the modified TAP.

Example 3 Whole class or trans-group discussions

After group activities, the leaders of the four groups made short presentations on how they arrived on what the experiment was all about and how they reached their conclusions regarding the unknown substances on their tables. All the four groups after individual and group brainstorming and discussions concluded that that the items on their tables were concerned with carrying out an experiment to identify substances A and B; and the solubility of B in A. Whatever evidence emerged from the experiment (not yet conducted at the time) would then serve as grounds for their claims about the two unknown substances. For example, at the class discussion level there were a few claims, counterclaims and rebuttals on the grounds that:

Group 3 made an extra claim: effects of solutes on the boiling points of liquids. T4 rebutted this claim by questioning the evidence used to substantiate the claim. According to T4, both A and B were unknown substances and that the available apparatus and their supposed usage were not enough to predict the above claim. In furtherance of his rebuttal, T4 asserted that in the absence of actual heating, boiling, weighing or mixing the substances it was presumptuous of T11 to corroborate the claim with assertion that: the boiling point of A is 100^o or that its density is 1.0. By evaluating the above discussions, the teachers made various claims and counterclaims with a single rebuttal which was directed at the evidence substantiating one of the counterclaims, in the context of the modified TAP, the whole class discussions attained level 3. The discourses above seem to support the effectiveness of DAIM framework for mediating co-construction of concepts.

Evaluating the levels of argumentation

In seeking answers to our second research question we examined the argumentation processes and scenarios to elucidate the various levels of argumentation attained. The various levels of argumentation were used as analytical framework to evaluate the quality of the arguments since they could determine whether the teachers are developing high-level argumentations skills. Higher incidences of rebuttal of claims and grounds by colleagues involved in the argumentation discourses could lead to the attainment of high level of argumentation (e.g. Simon et al., 2006; Ogunniyi, 2007a &b). It is clearly evident that during self-construction of solubility concepts at the intra-argumentation level, the teachers were able to come up with various degrees of evidence to substantiate their respective claims. This fortifies the notion that actively engaging in self explanations improves understanding (Chi et al, 1994). This conscious effort on the part of each individual teacher culminated in the attainment of level 2 of the modified TAP. In spite of the fact that this dialogue was done alone, the teachers explored, interrogated and critically evaluated whatever assertions they made. Since there were no concrete rebuttals or opposition of claims or grounds, level 2 of argumentation was also attained by all the groups during the discussions at the inter-argumentation level.

Even though there were no concrete rebuttals the teachers engaged in interactive discussions. The group leaders enhanced the articulation of discourse by mediating the small group discussions in order to arrive at sets of agreed claims and grounds. These were attained largely by the group members via co-constructing the various solubility concepts. As evident, the teachers used extensive explanations as part of the argumentation process to elaborate and co-construct solubility concepts. This is in agreement with previous postulation that explanatory and argumentative interactions are epistemic interactions that play a role in the co-construction of scientific notions (Baker et al, 2001). Baker et al (2001) further intimated that it may be ambitious to use argumentation dialogue as the primary medium for co-construction of scientific notions. Nevertheless, they considered argumentation dialogue as a potential means for encouraging critical thinking and awareness about the task in order to enhance understanding of the nature of the problem. In this paper, a three-tier discourse approach comprising of individual, small group and whole class discussions model was used to augment the dialogical argumentation pedagogy. Group leaders and workshop facilitators mediated the epistemic interactions to enhance efficient implementation of the argumentation. The scaffolding of knowledge co-construction ensured that dialogical argumentation was not merely used as a vehicle to enact the discourses.

During the whole class discussions, the level of argumentation attained was 3. This was an improvement upon the small group discussions which was at level 2. The teachers appeared to have reinforced their understanding of the various levels of argumentation, since the whole class unanimously agreed on the correct level of argumentation attained (i.e. level 3). The ability of the teachers to engage in dialogical argumentation was enhanced considerably since other assertions were also challenged. For example, in the course of the whole class discussions, T4 had the following arguments rebutted: B would release or absorb energy when dissolving in polar liquids; sugars would produce a viscous solution in polar liquids; salt solutions is not viscous; and that all sugars are opaque, very white while some are fine powders. These incidences of rebuttals in the whole class discussion seem to suggest that the teachers are not only critically analyzing scientific concepts but are also enhancing their levels of argumentation. What is evident from this snapshot report is that the teachers have begun to appreciate the value of argumentation not only as an instructional tool but also as a means for scaffolding knowledge co-construction. Further, as in an earlier study (Ogunniyi, 2007b) observation and interviews data (not reported for lack of space in this paper) showed that the teachers increased in knowledge and practical argumentation skills in the workshops.

Conclusion

From the foregoing, we have shown how dialogical argumentation-based instructional model when integrated with knowledge scaffolding could enhance school teachers' ability to co-construct the concept of solubility with their peers. We believe that the discursive worksheets and the three-tier discussion model employed in this work could be adapted as an exemplar for modelling other classroom based discourses. We have also demonstrated how increased epistemic interactions during dialogical argumentation-based discourses might have enhanced the quality argumentation and analytic skills that the teachers used. Although total evaluation of this ongoing project awaits future findings, it could serve as a useful indicator for assessing the effectiveness of DAIM. Nevertheless, the reported preliminary findings have shown DAIM to be a useful and an effective pedagogical framework for modelling scientific discourses for teaching and learning.

References

Akerson, V.L., & Abd-El-Khalick, F. (2003). Teaching elements of nature of science: A yearlong case study of fourth grade teacher. Journal of Research in Science Teaching, 40, 1025-1049.

Baker, M.J., de Vries, E., Lund, K. & Quignard, M. (2001). Computer-mediated epistemic interactions for co-constructing scientific notions: Lessons learned from a five-year research programme. In P. Dillenbourg, A. Eurelings & K. Hakkarainen (Eds.) Proceedings of Euro CSCL 2001: European Perspectives on Computer-Supported Collaborative Learning, Maastricht McLuhan Institute (ISBN 90-5681-097-9), pp. 89- 96. Maastricht, March 22-24, 2001.

Chi, M. T. H., de Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self explanations improves understanding. Cognitive Science, 18, 439-477.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of argumentation in classrooms. Science Education, 84 (3), 287-312.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Development in the use of Toulmin's argumentation pattern in studying science discourse. *Science Education*, 88 (6), 915-953.

Fraser, G., Lillestrol, E. & Sellevag, I. (1994). The search for infinity: solving the mysteries of the universe. London: Reed Inte3rnational Books Ltd.

Kittleson, J.M. & Southerland, S.A. (2004). The role of discourse in group knowledge construction: A case study of college students. Journal of Research in Science Teaching, 41, 267-293.

Ogunniyi, M. B. (2007a). Teachers' stances and practical arguments regarding a science- indigenous knowledge curriculum, paper 1. International Journal of Science Education, 29(8), 963-985.

Ogunniyi, M. B. (2007b). Teachers' stances and practical arguments regarding a science- indigenous knowledge curriculum, paper 2. International Journal of Science Education, 29(10), 1189-1207.

Popper, K. (2001). All life is problem solving. London: Routledge.

Schwartz, R.S, Lederman, N.G. & Crawford, B.A. (2004). Developing the views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. Science Education, 88, 610-645.

Simon, S.; Erduran, S; Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. International Journal of Science Education, 28(2-3), 248

Toulmin, S., 1958. The uses of argument. Cambridge University Press, Cambridge.

Van Eemeren, F.H. , Grootendorst, R. & Kruiger, T. (Eds.) (1987). Handbook of argumentation theory. Dordrecht-Holland: Foris Publications.

Ziman, J. (2000). Real science: What it is, and what it means. Cambridge: Cambridge University Press.