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Towards an Integrated Learning Strategies Approach To Promoting Scientific Literacy in the South African Context

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Аннотация

The focus of this paper is on selected recent South African research studies that have explored efforts to promote the discussion, writing, and arguing aspects of scientific literacy in primary and middle schools, particularly amongst second-language learners. These studies reveal improvements in the participants' abilities to both use the 'science notebooks' approach and argue their findings, as well as statistically significant improvement in their problem solving skills. The positive findings of these studies, and the call for attention to be paid to the fundamental sense of scientific literacy by a number of international researchers, resulted in the development of an integrated learning strategies approach. This approach not only specifically includes classroom discussion, argumentation and writing strategies to learn science, but also provides teachers with ideas and techniques to stimulate their learners to develop their own investigable questions, plan and execute a successful investigation in the classroom, and present their findings to an authentic audience. Findings on the effect of the strategy on learners' general literacy skills, both in their home language and the language of learning and teaching in their schools, are reported.

Ключевые слова: scientific literacy, general literacy, classroom discussion, argumentation, writing to learn science

Introduction

Concern around the apparent inability of science and technology education to attend to current societal issues and the negative perceptions of, and lack of interest in, science exists in both developing and industrial countries (Fensham, 2008). Shamos (1995) points out that the need to stimulate interest in science and prepare learners to become citizens who can make informed decisions is an imperative in all societies. However, developing countries, or countries in transition, regularly face the additional challenge of insufficient qualified educators to teach science (Earnest & Treagust, 2007). In addition, in previously colonised societies, the teaching and learning of science often takes place in a second or foreign language for both teacher and learner. This is particularly true in previously Anglophone colonies where both parents and teachers tend to perceive English as the language of socioeconomic power and mobility (Setati, 1998).

Language in science is not only an issue for second-language learners and teachers and, in recent years, there has been increasing research and recognition of the central role of language in learning science (Norris & Phillips, 2003; Yore & Treagust, 2006). These researchers, amongst others, believe that for someone to be judged scientifically literate they must be proficient in the discourses of science, which include reading, writing and talking science. Hand, Prain and Yore (2001), along with Norris and Phillips (2003), draw a distinction between the fundamental and derived senses of scientific literacy in that the fundamental sense requires proficiency in science language and thinking. Being proficient in the fundamental sense is a pre-requisite for being able to operate within the derived sense, that is, being able to make informed judgements on scientific societal issues (Hand, Prain & Yore, 2001; Norris & Phillips, 2003).

In the South African context, where teaching and learning most often takes place in a second language, poor performance in national and international tests of science achievement and in national systemic evaluations of literacy and numeracy (Department of Education, 2003) suggest that there is an urgent need to focus on scientific literacy in its fundamental sense in order to provide the necessary framework for engaging learners in the derived sense of scientific literacy. This paper therefore focuses on selected recent South African research studies which explored efforts to promote the talking, writing and arguing aspects of scientific literacy in primary and middle schools, particularly amongst second-language learners, as well as the scientific literacy strategy that was developed within the framework of these findings.

Background

In the past, South African children have achieved very poorly on international tests such as the Third International Mathematics and Science Study (TIMSS) in 1996 and the Trends in Mathematics and Science Study (TIMSS) in 2003. The South African grade 8 learners in the study were the lowest scoring group of the 50 participating countries in both mathematics and science on both occasions (Human Sciences Research Council, 2006). The results of several systemic evaluations of student performance by the South African government reveal that, on average, learners in primary and middle school are approximately three years behind where they could expect to be in terms of language, science and mathematics achievement (Department of Education, 2005). Similarly, the Progress in International Reading Literacy Study (PIRLS), which included the testing of over 30,000 children in grades 4 and 5 in 2006, revealed very low reading levels (Martin, Mullis & Kennedy, 2007). These reading levels varied very little between students who chose to write the test in their mother tongue or in the language of instruction at school - usually English (Fleisch, 2008).

During the period over which these (and other) tests took place there have been a number of curriculum reforms. A new curriculum, which places a greater emphasis on specific learning outcomes and the competencies that the learner must achieve, was developed to replace the previous traditional and content-based curriculum that was in existence in South Africa prior to universal franchise in 1995 (Department of Education, 2002, 2005). These changes included critical and developmental outcomes inspired by the new constitution of South Africa, and which are in keeping with the ideals of democracy, equity and redress (Department of Education, 2005). The science aspect of the curriculum has three major learning outcomes; viz., scientific investigations, developing knowledge and science and society, each with a number of assessment standards per grade operating within the core knowledge areas of matter and materials, energy and change, the Earth and beyond, and like and living. The approach is modem, based in constructivist learning theory and framed in Outcomes Based Education (OBE) terminology (Moll, 2002). The critical outcomes of the National Curriculum

Statement focus on the development of learners who are creative-critical-effective problem solvers, collaborators, responsible persons, collectors and analyzers of information, effective communicators and informed and skilled in the use of science and technology (Department of Education, 2005).

The South African Department of Education asserts that the main purpose of the Natural Science Learning Area (grades 1-9) is to promote scientific literacy. The departmental definition of scientific literacy encompasses the prevailing international definitions including the development and use of science process skills in a variety of settings, the development and application of scientific knowledge and understanding, and the appreciation of the relationships and responsibilities between science, society and the environment (Department of Education, 2002). Overall, the new South African curriculum purports to be highly supportive of the development of scientific literacy, but it appears that the changes that have been brought about on paper have not equated to transforming or improving maths and science education in the classroom (Christie, Butler & Potterton, 2007). Taylor and Vinjevold (1999) stated a decade ago that teachers did not have the knowledge base either to interpret the new curricula or to implement the intention of the policies. It appeared that many teachers, across the spectrum of schooling in South Africa, modelled surface forms of learner-centred activities without understanding the underpinning philosophies and it was found that what students knew and could do was dismal (Taylor & Vinjevold, 1999). Little appears to have changed to date (Christie, Butler & Potterton, 2007; Fleisch, 2008).

In the light of the above a selected number of studies on strategies designed to promote aspects of scientific literacy in the South African context are reported in this paper. These include promoting classroom discussion (Webb & Treagust, 2006), developing argumentation (Webb, Wilhams & Meiring, 2008), and the effect of using the science notebooks approach (Villanueva & Webb, 2008). Partially as a result of the findings of these studies, and based on the wealth of literature recently generated internationally (e.g., Bazerman, 1988; Klentschy, Garrison & Amaral, 1999; Baxter, Bass & Glaser, 2000; Hand, Prain & Yore, 2001; Norris & Phillips, 2003; Yore, Bizanz & Hand, 2003; Brown, Reveles & Kelly, 2005; Cervetti, Pearson, Bravo & Barber, 2005; Yore & Treagust, 2006; Yore, Pimm & Hsiao-Lin, 2007), an ‘integrated strategy’ for developing scientific literacy was developed and piloted in a deep rural setting in the Eastern Cape. After initial development the strategy was implemented with second-language English teachers teaching English second-language learners in a deep-rural area of the Eastern Cape; viz., the Tyumie Valley. The effect of the strategy is being researched in terms of change in teacher behaviour and understanding and learner problemsolving abilities, conceptual understanding and general and scientific literacy. Currently, many aspects of the project are in the data generation and analysis stage, but early results suggest, amongst others, improvement in aspects of the participating learners' general literacy skills (Mayaba, 2009).

Methods

Mixed method approaches were adopted for the studies which preceded and influenced the development of the integrated learning strategies approach to promoting scientific literacy mentioned earlier, as was the case for the research on the integrated learning strategies approach. These studies focused on the effects of introducing techniques to promote discussion, writing and argumentation in science classes in South Africa.

Classroom Discussion

The sample in this study (Webb & Treagust, 2006) was 12 matched grade-7 science teachers in similar type schools in urban, peri-urban and rural geographic and sociocultural milieus in the Eastern Cape, South Africa. Of the four teachers identified in each milieu (setting), one school (i.e., the teacher plus his/her class of pupils) was randomly chosen at the start of the study as a control group in order to allow comparisons with the experimental group. Each of the other three teachers was trained to facilitate discussion, that is, they were introduced to activities and strategies aimed at promoting or 'triggering' discussion between learners (Webb & Treagust, 2006). The control group teachers played no part in the teacher development activities and were unaware of the classroom discussion activities and strategies that were being promoted in the other schools.

Baseline classroom observations and initial measures of the participating learners' reasoning skills were made. The Raven's Sta ndard Progressive Matrices test (Raven, Court & Raven, 1995; Richardson, 1991) was used as a measure of reasoning skills. The data generated were treated statistically and analysed to provide descriptive statistics and analyses of covariance (ANCOVA) were applied with pre-test scores providing the comparative co-variates. Cronbach's alpha coefficient was used as an indicator of test reliability. As the learners participating in this study were all isiXhosa home-language speakers (but who are taught in English) the tests were administered in English by a fieldworker who was also a isiXhosa homelanguage speaker so that she could answer queries made by the participants in their home language if necessary.

A four-point scale classroom observation instrument was developed in order to quantify the classroom activities that took place during three video-taped classroom observation sessions per teacher. All teachers taught the topic of magnetism during this period. The criteria used to determine whether classroom discussion had taken place were the ability of learners to engage in the lexicon (use the words appropriately), use scientific explanations (apply connectives), and engage in discourses that included descriptions, predictions, explanations and arguments. A minimum criterion was used as a 'cut-off' point for judging whether classroom discussion had taken place or not (namely, that each of the above interactions had been exhibited at least once, and that two of the three were exhibited three or more times per classroom observation). All of the videos, narratives and interview reports were reviewed by two researchers who made a collective judgement as to whether discussion had taken place in any particular lesson. The participating teachers were interviewed at the end of each classroom observation session, and at the end of the implementation phase of the classroom discussion initiative in order to gain an understanding of their perspectives of the process (Webb & Treagust, 2006).

Science Notebooks

The sample in this study was seven grade 6 science teachers from primary schools in Port Elizabeth, South Africa. The teachers came from different schools that were broadly matched as institutions that are from previously disadvantaged communities, are similar in size and type, and which are considered neither currently dysfunctional nor excellent. Although eight teachers were invited to participate, only seven continued for the duration of the study resulting in four teachers serving in the control group and three teachers making up the experimental group (Villanueva & Webb, 2008).

Data generated included baseline information (in the form of interviews and classroom observations), post-intervention classroom observations with both the experimental and control group teachers, and reciprocal feedback sessions with the experimental group of teachers. A pair of researchers conducted each classroom observation using the Science Inquiry Observation Scale and came to consensus findings. Further quantitative data were generated by using the Science Notebooks Checklist. These instruments were developed and validated by researchers at the University of North Carolina - Wilmington (UNCW) and used in a number of science inquiry and notebooks studies (Nesbit, Hargrove & Fox, 2003; Nesbit, Hargrove, Harrelson & Maxey, 2004; Reid-Griffin, Nesbit & Rogers, 2005). Although the instruments were developed for American schools they were considered to be sufficiently general for use in the South African context. The interview protocols, however, were drawn up especially for this study and focused on context and classroom environment, as well as science writing and inquiry-based teaching.

The experimental group of teachers participated in two professional development workshops (total of six hours) on scientific investigations and the theoretical and practical aspects of using the Science Notebooks strategy. The topics chosen were based on the cohesive properties of water, properties of magnets and electric current (batteries & bulbs). The first classroom observations were conducted one week after the professional development workshops. Each participating science teacher was observed as they implemented the Science Notebooks approach in their classroom. Immediately following their classroom observation session, the teachers were interviewed. The learners individually completed Scie nce Notebooks records for three separate investigations and five notebooks from each class were randomly selected and analysed against the Science Notebooks Checklist. Throughout the intervention process the Science Notebooks of the same five learners per class across all three observations were analysed. Teachers from the control group were also observed, and interviewed three times after the initial baseline data collection process.

The Science Inquiry Observation Scale is designed to measure the degree of inquiry-based teaching used by the teachers in their science lessons. The instrument assessed six areas in relation to the scientific process: constructing a testable question, designing the procedure, implementing the investigation, collecting data, making scientific drawings and drawing conclusions. The assessment is based on a four point scale with an additional assessment (level zero) to indicate the absence of that component. Levels one through four are based on a continuum of teacher ‘telling’ to independent of ‘guiding’. For example assessment on ‘how well the teacher promotes learners independence in constructing an investigable question' has five possible scores ranging through zero (there is no evidence of a testable question) to one (teacher states a testable question), to two (teacher guides learners towards a testable question but ultimately frames the question), to three (through questioning teacher leads learners to a testable question), to four (learners generate testable questions independent of teacher guidance).

The data generated from teacher's classroom practice were based on the observers' assessment of the participating teachers' ability to carry out activities and behaviours which enable children to participate independently in scientific investigations. Whether these behaviours were translated in any way into learner achievement was investigated by examining their written records using the Science Notebooks Checklist.

The Science Notebooks Checklist instrument assesses the extent to which the work in the children's Science Notebooks reflects principles of scientific inquiry and investigations (Reid- Griffin, Nesbit & Rogers, 2005). This checklist was used to assess learners' writings in order to determine the degree to which they were able to construct a testable question, devise, implement and write up their procedure, collect data, their draw scientific illustrations, and draw conclusions (Nesbit, Hargrove & Fox, 2003).

Argumentation

This study investigated what two classes of 48 ninth-grade learners each were capable of doing when presented with a number of concept cartoons and an argumentation writing frame during their science lessons (Webb, Williams & Meiring, 2008). Concept cartoons consist of simple drawings and minimal text which show characters arguing about everyday situations (Naylor & Keogh, 2000). The belief is that the simplicity of the text and drawings makes them accessible to learners who are not fluent in formal language and scientific terminology, and that the various viewpoints displayed in the concept cartoons reinforce the idea that there may be competing viewpoints that need to be debated. They also believe that this beginning point of inquiry serves as motivation for learners to want to know more and that the visual presentations both stimulate and legitimise their use of argumentation in the process of trying to know more (Naylor & Keogh, 2000).

The writing frames used in the study were designed to assist learners to frame an argument around what they saw in concept cartoons. The frame probed their ideas by requiring them to respond to statements based on a revised version of Toulmin's (1958) argumentation model (Simon, Erduran & Osborne, 2002). Statements in the writing frame such as 'My idea is that...' requires that the learners choose a claim to one of the opinions in a concept cartoon. By completing the 'My reasons are that... ' they provide data to support the claim they have made. The third section of the frame; viz., 'Arguments against my ideas might be that...' forces the learner to think of ways in which others may disprove his or her claim (identify rebuttals). The I would convince somebody that does not believe me by...' section is aimed at getting the learner to provide suitable warrants to link his/her claim or counter claim to the data that he or she provided for the claim. Finally the 'The evidence I would use to convince them is that... ' section pulls together the data, warrants and backings to support the claim that they have made in the first section of the learner frame. The quality of their written arguments was then assessed using Erduran, Simon and Osborne's (2004) cluster model for evaluating argumentation.

The study was conducted during normal teaching sessions and the cartoons chosen fell within the planned science work schedule planned for the period, that is, (i) rusting (rusty nails in a sealed jar), (ii) seeds left to germinate in the dark, (iii) water condensing on the outside of a jar of water being heated by flame from a spirit burner, (iv) the nature of bubbles in boiling water, and (v) the effect of bubbles escaping from a bottle of lemonade on the mass of the lemonade (Williams, 2006). The learners were firstly introduced to a concept cartoon with little to no explanation of the purpose of the exercise to get an initial idea of learners' reaction to the cartoons and writing frame. Thereafter the process to be followed and objectives of the exercise were explained, and the learners were provided with different concept cartoons on a further three separate occasions. They were explicitly instructed, encouraged and assisted to engage in argumentation and the characteristics of authentic discussion were discussed with the children each time they engaged in an activity (e.g., you are expected to question one another, you are not expected to agree with one another, respect one another' s' ideas, rules of politeness apply, etc.) and they were 'walked' through what was expected in each section of the argumentation writing frame, for example, that the 'My idea is...' section of the writing frame is where they should write their claim - what they believe to be true based on what they found out and had argued to agreement during the activity. After their discussions they were

Integrated Learning Strategies Approach to Promoting Scientific e xpected to record the process that had taken place, and the mutually agreed decisions that had been made on the writing frame.

As noted earlier, Erduran, Simon and Osborne's (2004) cluster model was used to assess arguments on a five point ordinal scale from low to high levels of argument. These levels reflect arguments that are simple claims versus counter claims (level one); arguments consisting of claims with supportive data, warrants or backings, but do not contain any rebuttals (level two); arguments with a series of claims or counter claims with supportive data, warrants or backings with the occasional weak rebuttal (level three); arguments have claims with a clearly identifiable rebuttal (level four); and extended argumentation with more than one well argued rebuttal (level five).

Integrated Strategies Approach

This study integrated the approaches and methods of the studies described above, but included research on changes in general (overall) literacy exhibited by children participating in the process. The general literacy apect measured the reading, writing, talking and listening skills of learners before and after the implementation of the science literacy strategy over six months. The sample comprised of five grades six and seven (multigrade) classes in seven primary schools situated in the rural foothills of the Hogsback Mountains in the Eastern Cape. Learners ranged between 11 and 14 years of age and both the learners and teachers were isiX- hosa first language speakers. Five schools were randomly chosen to represent the experimental group which participated in the strategy while the remaining two schools constituted the control group.

The literacy baseline and post-tests that were used were initially designed for the British Department for International Development (DfID) sponsored Mpumalanga Primary Schools Initiative evaluation (Webb, Glover, Cloete, England, Feza, Hosking, King, Kruger, Morar, Nyamazane & Wessels, 1999). These tests were translated into the home language of the teachers and learners (isiXhosa) who participated in the research project. The aim was to test learner's literacy levels in both their first language and the language of teaching and learning (English). The children's reading comprehension skills, ability to make inferences based on what they have read, and their ability to complete a paragraph in the form of a writing frame based on their interpretation of diagrams, were tested. Their listening skills were tested by requiring them to listen to a story and then answer multiple choice questions based on what they had heard. They then had to follow instructions given, for example, they were asked to complete a diagram by following instructions given by the researcher.

Writing skills were tested by requiring the children to write a story based on pictures provided, i.e., to see if they could transfer information from a visual to a written mode, could write coherent meaningful sentences based on the pictures, could interpret the visuals, and could write grammatically meaningful sentences. They were then asked to discuss something the researcher presented to them, e.g., they were asked whether they thought that if a feather and a blackboard duster dropped from the same height and the same time would reach the floor simultaneously. They were asked to discuss what they thought and explain their answers to the researcher and provide insight into their discussion. Their speaking ability was probed further by asking follow-up questions on what they had said. The quantitative data generated by the tests were treated statistically and analyses of variance (ANOVA) techniques were applied

A four-point scale classroom observation schedule was used to determine whether learners in these classrooms are given opportunities to read, listen, write and speak during the implementation of the scientific literacy strategy. These data were used to determine whether the scientific literacy strategy had been successfully implemented and to assess possible weaknesses in terms of implementation. The teachers and learners were interviewed singularly and in focus groups respectively to gain insight into their perspectives of the general literacy aspects of the intervention.

Research Findings

The results of the classroom discussion, writing to learn science, argumentation and integrated learning strategies approach studies are reported below.

Classroom Discussion

Qualitative data from the classroom observations in this study revealed that, in terms of the criteria for discussion used in this study, discussion did take place in the majority, but not all, of the experimental groups’ post-intervention lessons observed. Classroom observations also revealed that discussion of an exploratory nature had not taken place in any of the control groups' lessons. A notable point from the interview data was that all members of the experimental group of teachers agreed that making the 'rules of the game' of classroom discussion transparent helped them greatly to facilitate discussion in their classrooms.

Data from the Raven's Standard Progressive Matrices (RSPM) pre- and post-tests of reasoning (n=1192; --- = 0.84) indicated a statistically significant difference (p=0.000) between the pre- and post-tests scores, and between improvements in scores of the experimental and comparison groups. The five sets of 12 problems (60 in total) were analysed separately to investigate the levels of complexity of reasoning at which gains were made (the sets increase progressively in difficulty from sets A to E). Analysis of variance (ANOVA) of the Raven's data indicated that the greatest differences between the experimental group's and comparison group's mean gain scores were in sets A and B (p<0.001). The effect sizes were low, but were high enough to be considered of practical importance, that is, greater than 0.2. There was also a statistically significant difference (p<0.05) between the experimental and comparison groups in Raven's set D. No statistically significant difference between the experimental and comparison groups was recorded in sets C and E (p=0.16 & 0.84, respectively).

The South African pre-test 50 percentile score fell at a value of 21, while the United Kingdom (UK) 50 percentile norm for 12 year-old children falls at a value of 38. However, the post-test 50 percentile for the South African sample fell at 35, a figure that approximates that of the UK norm and which represents a considerable improvement in scores (Webb & Trea- gust, 2006).

Statistically significant differences between overall RSPM pre- and post-test scores by pupils in the urban, peri-urban and rural groups of schools were recorded at the p<0.01 level. The greatest total gain was measured in the urban group (5.68), followed by the rural group with a gain of 3.83 and then by the peri-urban group with a gain of 3.22.

Science Notebooks

After implementation of the Science Notebooks approach with the experimental group of teachers, the data generated through classroom observation revealed an overall increase in aggregate scores (sum of five-point scale scores for developing an investigable question, designing an experiment, data collection, scientific drawing and concluding) for the three teachers who had participated in the Science Notebooks approach workshops (Figure 1). This general pattern of increasing scores over time was reflected in each individual teacher's case from the baseline observation until the third and final lesson.

The improved performances noted in Figure 1 were, however, not equally evident across all categories in terms of magnitude, but were similar in terms of a trend towards improvement over time in almost all cases, as is shown in Figure 2 using the teachers' average scores on a five point scale. Overall, the experimental group of teachers was observed to progress from not being able to generate meaningfully investigable questions during the baseline lessons observed, to all being able to lead their learners towards generating a testable question to some extent. In all cases observed the teachers had to frame the final statement of the investigable question for their learners, yet the amount of input they had to make in terms of the other categories of the Science Notebooks process decreased over time. The teachers showed little inclination to get their learners to include scientific illustrations in their reports, but this aspect of the Science Notebooks approach did take place during the third investigation observed and learner generated illustrations were recorded in their Science Notebooks (see Figure 3).

During the same period the control group displayed minimal to no change in their teaching practices from the baseline ratings through their three classroom observations. They continued with traditional methods of expository teaching, rote learning and the occasional observation type practical activity. Despite that fact that all of these science teachers have been trained by the provincial Department of Education on the learning outcomes and assessment standards for scientific investigations as described in the national curriculum statement (Department of Education, 2002), learners did not write notes, create scientific drawings or draw conclusions based on their observations or the teacher's lesson, as could be expected (Villanueva & Webb, 2008).

Inspection of the sample of learners' science notebooks revealed that in all but one of the records examined, the children had simply copied their teacher's investigable question and that there was no quantifiable improvement in this component of the science notebooks approach over time. There were, however, quantifiable improvements in terms of the learner's ability to successfully implement the design, collect data, construct scientific drawings and construct a conclusion. These improvements are illustrated in Figure 3 where the percentages of the entries per sample (n=45) at levels three and four (i.e., satisfactory achievement) are plotted for each component being assessed. Level four scores indicate that the learners were able to generate their own information in a substantially complete and satisfactorily accurate manner while level three denotes that some details were missing and that the account was judged to be incomplete, but generally meeting requirements. These two levels have been combined in Figure 3.

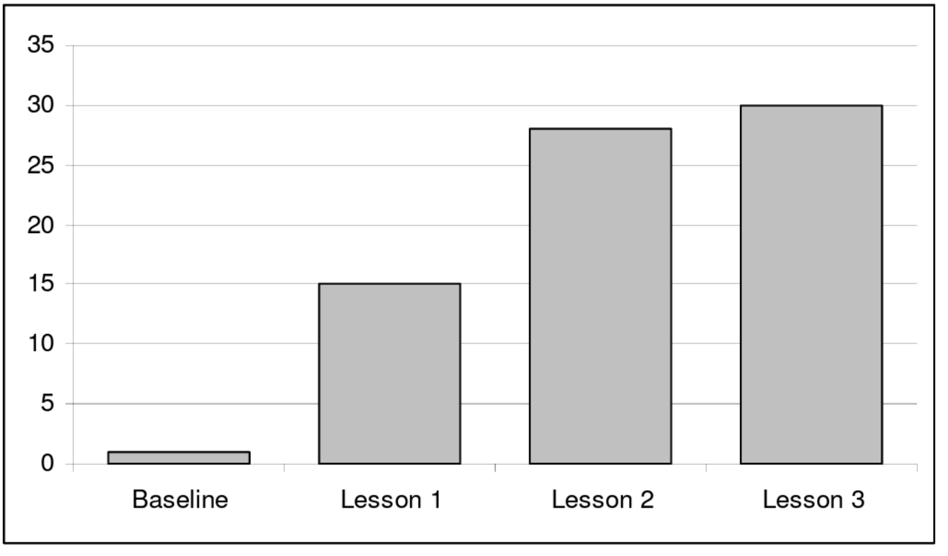

Figure 1. Aggregate science notebooks teacher implementation (classroom observation) scores over time for the three teachers who participated in the science notebooks approach workshops.

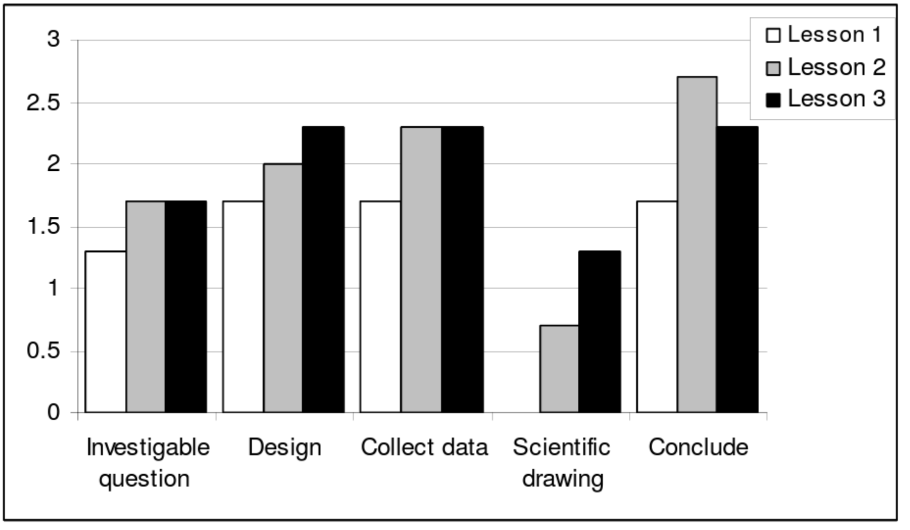

Figure 2. Average S*cience Notebooks* teacher implementation scores per catego-ryassessed over time for the group of three teachers who participated in S*cience Notebooks* approach workshops.

The number of learners who used scientific drawings in their reports was initially very low and only in the final sessions did the learners appear to understand that this was a legitimate and valued way of reporting. All 15 learner notebooks revealed that they relied on their teachers to dictate a conclusion for their first investigation report. In the second Science Notebooks entry on magnetism, three learners managed to draw valid conclusions on their own and report them in their own words (level four), while three wrote up their conclusions in their own words in a manner that was judged to be incomplete or not entirely accurate (level three). In the third and final investigation the notebooks entries revealed that six learners could draw valid conclusions on their own and give a written report in their own words (level four) and three were able to write an explanation in their own words, but which were judged to be incomplete (level three). These data suggest that progress was made through practice by both the teachers and their learners while engaging in the Science Notebooks approach to carrying out scientific investigations.

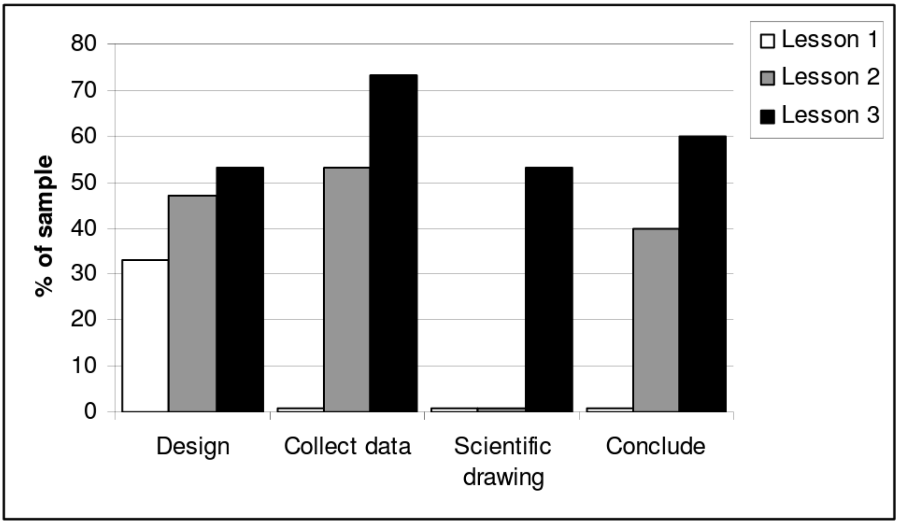

Figure 3. Percentage of entries (n=45) per component in the learner *Science Notebooks* that were judged to be at a satisfactory level of achievement (i.e., at levels three and four) for each of the three lessons.

Argumentation

The baseline observation data revealed that while there was much talk and, on occasion, opposition to the views of others, the ideas generated were generally not based on supportive data, but on intuitively based claims (level-one type argument). Only in one case was any attempt made to provide backing for the argument. No substantive or acceptable data were provided to support the claims made by the learners at any stage in these exercises, nor were the weak attempt at rebuttals considered eligible for the record. As such, the learners as a group were classified as operating at the lowest level, that is, at level one.

The data generated from observation and the learners' writing frames, once the purpose of the concept cartoons and writing frames had been explained, were found to be substantially similar, that is, showed the similar usage of claims, data, warrants and rebuttals, and were therefore combined for presentation in Table 1. The data provide a summary of the baseline, and the three concept cartoons levels of argumentation achieved per group. The two classes in their entirety were recorded as groups 1 and 2 for the purposes of the baseline assessment, thereafter the results of six groups - three per class and comprising 50% of each class - were recorded.

Table 1. Summary of the levels of argumentation reached per group of eight learners per concept cartoon session (* = attained)

Level	Initial Cartoons		Burning						Air bubbles?						Lemonade bubbles					
5																				
4																				
3												*			*	*			*	*
2						*	*			*		*			*	*			*	*
1	*	*		*		*	*		*	*		*		*	*	*	*	*	*	*
Groups	1	2	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6

Integrated strategies approach

Classroom observations revealed that in general the teachers chose to teach in their home language and code-switch into English on occasion (the official language of learning and teaching). It was also noted that the learners used isiXhosa exclusively during classroom discussion. All of the lessons observed suggested that the teachers had an adequate understanding of the scientific literacy strategy, but that they provided no planned activities to test their learners listening skills. It was also apparent that learners struggled to share their ideas when opportunities were provided for classroom discussion and that their science notebooks were often incoherent and that they struggled to read.

The data generated by the general literacy study pre- and post-tests were computed using analysis of variance (ANOVA) techniques. This was done to interrogate differences between the experimental and control groups mean scores for the reading, listening, writing and talking aspects of the literacy tests; gains made during implementation of the strategy; and differences between the scores dependent on the language used. The most significant findings of these test data are summarized in Table 2.

Discussion

The data generated by the discussion, writing to learn science, argumentation and integrated strategies approach studies suggest that the South African teachers who participated were receptive and able to implement, to varying degrees, the strategies presented to them.

Classroom Discussion

The apparent effects of promoting classroom discussion on learners Raven’s test scores are notable. There was a clear and statistically significant improvement in the reasoning scores of pupils who participated in the classroom discussion initiative over those of the control groups, and the scores began to approximate those of their counterparts in the United Kingdom.

Generally the Raven’s test results appear unambiguous and easy to explain. The most significant improvements made were in question sets A and B as would be expected, that is, the least challenging of the progressively more difficult sets of questions. However, the statistically significant improvement in question set D requires some thought. The suggested explanation is that even though the mean initial (pre-test) scores were low, there were groups of pupils who were already scoring fairly well on question sets A and B and who were able to improve on their post-test scores in question set D, possibly as a result of intellectual stimulation. As the scores in question set D started from a very low base (pre-test data), an improvement in scores by a relatively small number of participants could possibly produce a statistically significant result. Also, as with improvements recorded in question sets A and B, this could be attributed, in part at least, to the environmental influences and cultural opportunities alluded to by Raven, Court and Raven (1995) - in this case taken to be exposure to classroom discussion activities.

Table 2. Main differences between the experimental and control groups for the reading, listening, writing and speaking pre- and post-tests

Reading	• The control group scored statistically significantly higher in reading in English in the pre-test but this figure fell in the post-test to the point where it was no longer statistically significant • The experimental group's mean scores for reading in English improved statistically significantly more than the control group's did after the treatment (at the 99% level of confidence) • The mean difference between the English and isiXhosa reading scores was significantly different in favour of isiXhosa in the pre-test, but there was no statistically significant difference in the post-test
Listening	• The control group scored statistically significantly higher than the experimental group in listening in English in the pre-test. This figure fell in the post-test but remained statistically significantly better than the experimental groups mean score • The experimental group's English and isiXhosa mean scores improved by a statistically significant amount (9.2 and 11.5 points respectively) over the control group's changes in scores • The mean difference between the English and isiXhosa listening scores was significantly different in favour of isiXhosa in both the pre-test and in the post-test
Writing	• The control group scored slightly better (but not statistically significantly) than the experimental group in the writing pre-test in isiXhosa, but this result was reversed in the post-test where the experimental group scored statistically significantly better in the isiXhosa writing test • There was no statistically significant change in the experimental group's writing skills in English over the control group after the intervention but there was a statistically significant improvement of their scores over the control group's scores in writing in isiXhosa (13.5 points) • The mean difference between the English and isiXhosa writing scores was significantly different in favour of English in the pre-test, but changed to being statistically significantly different in favour of isiXhosa in the post-test
Speaking	• There were no major differences between the talking pre- and post-test scores in English or isiXhosa in the pre- and post-tests • There were no statistically significant differences noted between changes in scores between the pre- and post-test scores of the experimental and control groups (small sample size) • There was no statistically significant mean differences between the English and isiXhosa speaking scores in either the pre- or post-tests

Science Notebooks

The Science Notebooks baseline study suggests that it is more than likely that prior to the intervention the participating learners were seldom, if ever encouraged to ask questions or to communicate their thoughts in the classroom through either oral or formal science writing activities. This remained the case for the control groups of students throughout the study. In contrast, there were improvements in a number of learners' abilities to draw conclusions and provide written reports in their own words in the experimental group over the period of the study. However, even after three attempts at implementation, many learners remained dependent on their teachers for their investigable question, and many others for their procedures, data collection, drawings and conclusions.

The problem of getting children to formulate their own investigable questions is one which has been shown to be common internationally (Cheong, 2000; Heil, Amorose, Gurnee & Harrison, 1999), and it should be remembered that for many science teachers providing learners with the opportunity to pursue open-ended inquiry is usually not part of their current practice. It is therefore important that the support given to teachers should explicitly focus on how they can engage learners in the approach so that they do ask questions, describe objects and events, test their idea with what is known, and communicate what they are learning (Chiappetta, 1998), a shift in approach which probably requires a significant amount of support from educator development agencies (Edelson, 1997). As such, Ruiz-Primo, Li & Shavel- son (2002) caution that without sufficient support Science Notebooks writing may be approached mechanistically, a process which results in ineffective implementation. Baxter, Bass and Glaser (2000) warn that the viability of the Science Notebooks approach depends on how it is used by science teachers in their own teaching and learning environments.

Many researchers argue that emulating and communicating authentic scientific investigations helps lead teachers away from the unsophisticated notion of science as a process in which learners simply gain knowledge and learn process skills towards a richer understanding of science, which includes scientific concepts, reasoning and critical thinking (Bybee, 1997; Fulton & Campbell, 2003; Miller & Calfee, 2004; Mintz & Calhoun, 2004; Ruiz-Primo, Li & Shavelson, 2002). Fulton and Campbell (2003) believe that by utilizing Science Notebooks for writing, discussing and reflecting exercises, learners begin to focus on the extent to which they understand the content. Hand, Wallace and Yang (2004) also point out that the act of focusing on content enables learners to make meaningful connections with their prior experience.

In the light of the well documented success of the approach in western societies, and the limited data generated in this study, it appears that further investigation of the applicability of the use of the Science Notebooks approach in the South African context is warrented. The viability of the approach may be particularly useful in the context of previously disadvantaged schools where our teachers often appear unable to communicate attitudes of curiosity, respect for evidence and critical reflection necessary for the development of higher-order cognitive skills (Taylor & Vinjevold, 1999).

Argumentation

The summary of the levels of argumentation reached per group of learners per concept cartoon session (Table 1) might seem to suggest progression over the time as learners worked with the concept cartoons and learning frames. However, overall the results were patchy (group 3 did no better in activity four than they did in the initial activities and groups 4 and 5 showed decreased ability after initial improvements), the research design did not include matching possible degree of difficulty or qualitative differences between the concept cartoons, the design was not really capable of distinguishing other possible reasons for improvement, for example, practice, and the sample of learners was limited.

Nevertheless, what the limited data do suggest is that there is promise in using concept cartoons in South African science classrooms to provoke argumentation and to stimulate learners' thinking, and they also suggest that linking these cartoons with writing frames to scaffold learners' thinking adds value. The findings of this intervention study also seem to corroborate Shakespeare's (2003) contention that argumentation is a process that takes time and skilful and purposeful implementation by teachers if it is to be adopted and fully utilised by learners. These inferences have implications for teachers and teacher development. Firstly, teachers need a thorough understanding of what is required of authentic discussion and argumentation and these approaches strengths and limitations before they can be expected to implement the strategy in a meaningful way. Also, the fact that successful implementation of the strategy takes time (Shakespeare, 2003) suggests that teachers will need a fair degree of support in terms of a deeper understanding of the how the approach fits into their curricula (including assessment strategies), and where they can find materials (concept cartoons) that they can use in their classrooms.

Another question that might be asked is 'what is the place and value of introducing concept cartoons and argumentation writing frames in South African schools within the current curriculum?' I argue that the use of concept cartoons and argumentation writing frames should be able to add value to Learning Outcome 1 of the

National Curriculum Statement: Scientific Investigations (Department of Education 2002) by allowing learners to air their alternative conceptions, come to authentic explanations for what they observe (Lipman, 1991), develop reasoning (Mercer, Wegerif & Dawes, 1999), and formulate their own investigable questions. Similarly, the strategy can enhance both Learning Outcome 2: Constructing Science Knowledge by developing understanding (Edwards & Mercer, 1987), promoting scientific thinking (Lipman, 1991; Perkins, 1994), as well as Learning Outcome 3: Science, Society and the environment by promoting communication (Barnes & Todd, 1977), values (Lemke, 1990) and scientific literacy (Yore, Bisanz, & Hand, 2003; Yore & Treagust, 2006).

There are, however, at this stage more questions than answers. For example, is the inability of some learners to engage in argumentation and move beyond level one linked to their knowledge levels, or whether providing apparatus and allowing the learners to perform the experiment themselves would have any impact on the argumentation process. But it seems reasonable to suggest that the approach is worthy of further investigation in the context of the South African curriculum (and most modern curricula) and may be important in terms of formulating effective teacher development strategies to embed the approach within a culture of scientific literacy.

Integrated Strategies Approach

The most interesting finding of the general literacy aspect of the integrated strategies approach study were the statistically significant improvements in the participating learner’s home language (isiXhosa) listening and writing skills. These results are interesting as one might expect home language to be well developed at grade 6/7 level, and not easily susceptible to relatively short term interventions such as the scientific literacy strategy. However, there are a number of studies which suggest that if language is not properly developed in a child’s home language before being introduced to a second language, both will suffer (Heugh, 2000). This seems to be the case in this study because both the experimental and the control group mean scores in English and IsiXhosa pre-tests reflected very low levels of learner’s performance. Perhaps a less surprising finding, as the reading materials provided were in English only, was that there was also an improvement in learners’ English reading skills. Nevertheless, what is of issue is that the learners were equally underdeveloped in both languages and the fact that, despite some statistically significant improvements, they still performed below par after the intervention (Mayaba, 2009).

An Integrated Teaching Strategies Model for Developing Scientific Literacy

The findings of the above studies, and those of Norris and Phillips (2003) and Yore and Trea- gust (2006), call for attention to be paid to the fundamental sense of scientific literacy. As such an approach was developed that not only specifically includes classroom discussion, argumentation and writing to learn science, but which provides teachers with ideas and techniques (including reading) to stimulate their learners to develop their own investigable questions, plan and execute an investigation in the classroom, and present their findings to an authentic audience. The approach models what scientists do; viz. read, talk, identify a problem, plan an investigation, do experiments, read more, argue their findings, and present them in a number of ways depending on the audience. Put simply, the strategy aims at:

- Enhancing reading to learn science and learning to read for science;
- Improving classroom discussion and exploratory talk towards investigable questions;
- Facilitating planning and doing an investigation in the classroom;
- Scaffolding writing to learn science;
- Scaffolding argumentation and critical thinking; and

The basic tenets of the model are illustrated in Figure 4.

From Figure 4 we see that the stimulus (the reading material, discrepant event, concept cartoon, etc.) not only provides the stimulation for discussion, but can also help access some of the prerequisite information needed for meaningful discussion to raise investigable and researchable questions. The discussion that ensues and the investigable question generated, enables the planning and execution of the investigation. Once the line of learning is drawn in the children’s science notebook, that is, they have drawn all the conclusions that they can from their classroom investigation by using the data they have generated, further reading and research allows them to go beyond the limits of their investigable question. This means that they can explore through other forms of information gathering the non-investigable but researchable questions that were raised as part of their earlier discussions. Finally, getting learners to record their arguments within a writing framework not only improves their argumentation techniques, but provides opportunities to improve their understandings of the nature of science, scientific processes and procedures, the notion of audience and presentation requirements.

There are a number of implications and obstacles for teachers and for teacher education when introducing the integrated learning strategies approach to promoting scientific literacy. First, for science teachers there may be issues in terms of reading techniques to be considered, particularly if the students are second-language learners. Practicing teachers must be au fait with current practices and science-teacher educators must ensure that they introduce their students to effective language and literacy strategies. Second, teachers also need to become competent and at ease in terms of promoting classroom discussion amongst their learners and must ensure that there are ample materials available for their learners to use to promote reading and researching to extend their line of learning. Third, they must also be thoroughly acquainted with understandings of the nature of science and the processes and procedural knowledge that need to be developed if their learners are to develop their scientific literacy in an authentic sense.

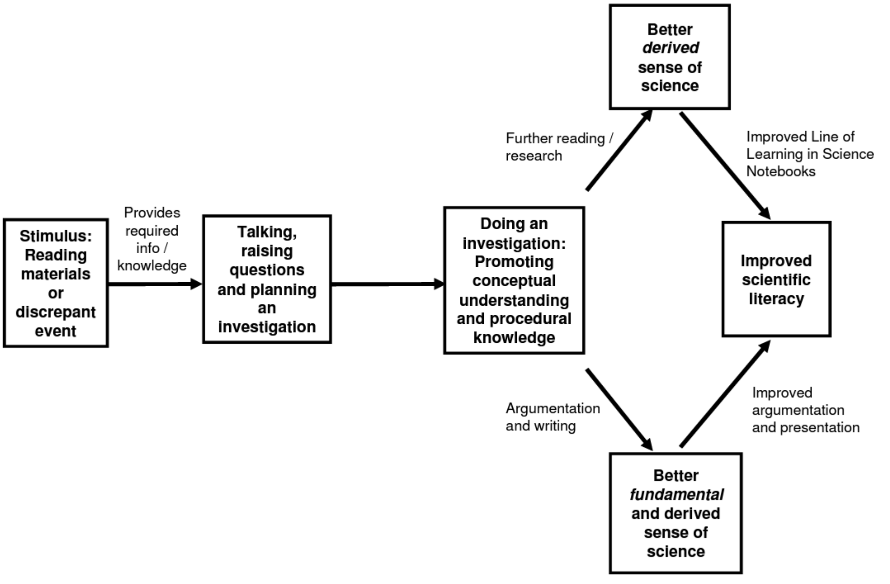

Figure 4. Basic representation of the integrated teaching strategies model for improved scientific literacy.

Teachers have to assess their learners' levels of scientific literacy in all aspects covered by the strategy, that is, the learners' ability to read, write, discuss, plan, do, argue and present their findings. These aspects can be assessed both formatively throughout the process and summatively by assessing the products of the strategy, as shown in Figure 5. What also must be remembered is that although the model presented in Figure 4 seems to imply that the reading, writing, talking and doing aspects of the strategy take place at discrete intervals, this is not the case.

As shown in Figure 5 they take place whenever applicable. This diagram also further teases out the prediction, procedure, data collection and conclusion aspects of the inquiry process, as well as the importance of teacher directed discussion and teacher demonstration as ways of extending the fine of learning. Also illustrated in this version of the model is the importance of student generated ideas and words, scientific vocabulary, new applications and questions raised during the process. This model also illustrates that findings can be shared in a variety of ways, for example, reports, publications, oral and dramatic presentations, etc. Finally, in terms of records of students' work, each investigation with the concomitant evidence of learner output and assessment can be kept in a portfolio for presentation to their parents, peers and any other interested parties.

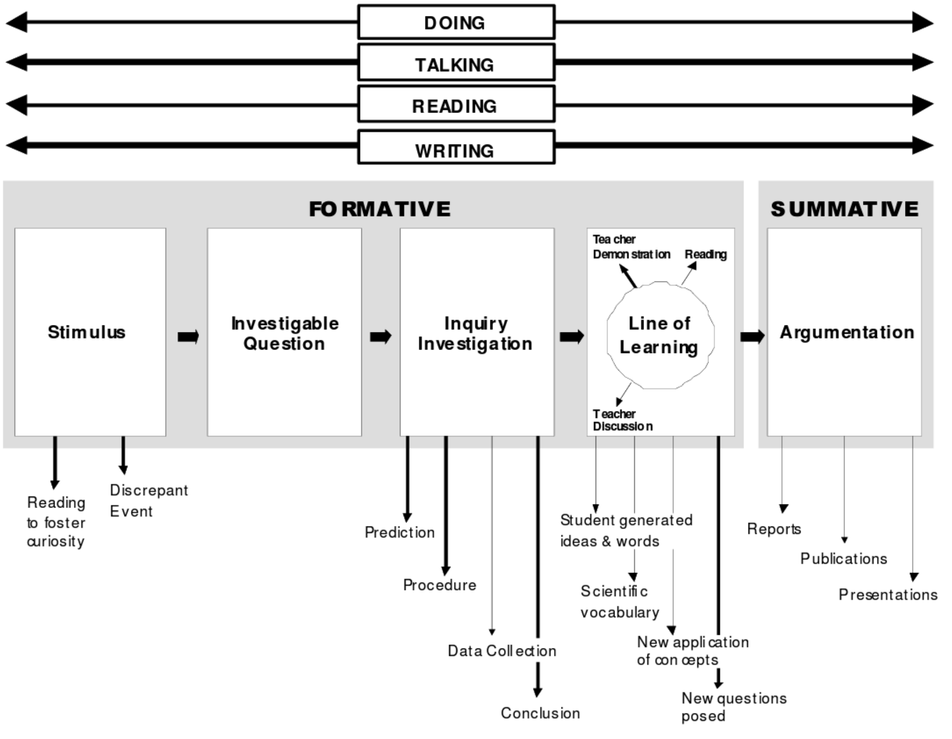

Figure 5. Representation of the integrated teaching strategies model for improved scientific literacy showing the continuous and integrated nature of the reading, writing, talking and doing aspects of the model and opportunities for assessment

Concluding Remarks

Although Yore and Treagust (2006) note that learning to talk read and write science is important as they enable learners to argue meaningfully about science issues, in most of the schools sampled for this particular study it appears that an added problem exists because learners are taught in a language which is not their mother tongue, a problem that has regularly been reported in South African literature (Setati, 1998, Setati, Adler, Reed & Bapoo, 2002). It is therefore not surprising to find that the South African TIMMS scores are by far the highest for children who are schooled and wrote the test in their mother tongue (Howie, 2005). Problems of bilingualism are not confined to South Africa. Alidou and Brock-Utne (in Alidou et al., 2006) report that classroom observation studies conducted in several countries in Africa (Benin, Burkina Faso, Guinea-Bissau, Mali, Mozambique, Niger, South Africa, Togo, Tanzania, Ethiopia, Ghana, and Botswana) reveal that the use of an unfamiliar language such as English often results in traditional and teacher-centred teaching methods, e.g. chorus teaching, repetition, memorization and recall. Teachers do most of the talking while children remain silent and passive. When teachers use English mainly for explanation, rote learning of procedures takes place and opportunities for developing meaningful learner-centred scientific talk and writing are limited.

As such, the integrated strategies approach to scientific literacy that was developed clearly identifies the role of language in learning science and promotes writing, talking, reading, discussion and arguing. These influences, although perhaps not as acute, are also pervasive amongst first-language speakers as they grapple with what Yore and Treagust (2006) describe as the ‘three-language’ (casual home language, instructional language, science language) problem that exists for most science learners.

The statistically significant differences between overall Raven’s pre- and post-test scores by pupils in the urban, peri-urban and rural schools recorded in the classroom discussion study suggest that other issues of social capital may also play a role in learner achievement. Therefore, although the findings of the studies reported in this paper generally support the notion that an integrated learning strategies approach is probably a viable option, it appears that there are overlays of influence which include both language and social capital that need to be taken into account if we are to meet Fensham’s (2008) goal of developing scientific literacy for all.

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