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Unawareness to Production, Dropout to Innovator—Primary teachers' understanding and use of a science, technology and society approach to science teaching

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This paper investigates the process of teacher change in a group of 8 primary school teachers during their exposure to a science, technology and society (STS) approach to teaching Science in Swaziland. The research aimed to establish the effect of support given to teachers in using the approach through a series of workshops, followed by a 5-week supported implementation of the unit 'matter and energy'. An analysis of the way in which the STS approach impacted on the classroom practice of the teachers yielded 2 outcomes that were hierarchical. First, teacher understanding of the approach was observed to go through levels of unawareness, recognition of differences in approach, utilisation, personalisation and production. Second, the teachers' level of use of the STS approach was observed to have been affected by their levels of understanding, characterised by the following typologies: dropouts, strugglers, domesticators, succeeders and innovators. Some relationship between levels of understanding and typology of use was found, however, the level of understanding was not the exclusive determinant of typology of use. Only teachers reaching the utilisation level were able to use the innovation in a sustainable way, while those at the level of unawareness were able to become domesticators, adapting the innovation to their usual teaching approach.

Keywords: *Context-based approaches; STS; Primary teachers; Teacher change*

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Introduction

Curriculum change and teacher change should belong together as a matter of course, but this logical partnership is seldom a foregone conclusion in practice. The challenge of achieving both is complex and continues to occupy the attention of all education stakeholders. Most accounts of curriculum change are intricately tied up with institutional or school change (see e.g. Fullan, 1992; Hewson, Kahle, Scantlebury, & Davies, 2001). However, it is the teacher element that remains the most elusive consequence of curriculum change. Teacher change is most sought after in developing education systems, where other forms of support remain limited, and the human element remains the most important form of input offered to learners.

Many developments in science education recognise the current ineffectiveness of traditional teaching methods in improving learners' ability to apply knowledge in real-life situations, to think critically, to solve problems, and to contribute to personal and national development (Anderson et al., 1994). One approach to achieving these goals is through a science, technology and society (STS) approach, which has proved to be particularly attractive, due to its use of relevant applications as a starting point for the teaching of science. The STS approach is known by different names, including 'applications-led science', 'science in society' and 'context-based teaching practices' (Bennett, Lubben, & Hogarth, 2007). Its main thrust is to teach science through its applications, using authentic activities wherever possible. It shows the links between school science and real life. Lessons are characteristically started from such means as a storyline; a play; student activity based on real or potentially real experiences of the learner; role-plays; current events and problems in society; or any information from the media that is related to the science concepts in the lesson. These are used to lead to the lesson to improve the level of learners' engagement with the lesson, as they come to terms with the science it imbues. The lesson ends with the application of the learned science in a real-life situation.

A number of recent and less recent attempts have met with success internationally (e.g. Stolk, de Jong, Bulte, & Pilot, 2011; Yager & Weld, 1999) including in Swaziland, the country of this study (Stronkhorst & Akker, 2006). Swaziland has implemented STS approaches at all levels of schooling (e.g. Putsoa & Dlamini, 2005). Successes at the junior secondary level (Lubben, Campbell, & Dlamini, 1995) have precipitated the extension of the approach to the primary school level. However, in Africa—where there is uneven capacity to support innovation—such changes pose particular challenges for curriculum developers and researchers (Rogan & Grayson, 2003).

Despite the successes cited above, the realities of the classroom have made changes in practice difficult to implement (e.g. Tsai, 2001). In addition, there is a dearth of studies focusing on primary school teachers' ability to adapt to the use of STS approaches. Primary teachers are usually non-specialists in science, and lack confidence in their understanding of science concepts (Shallcross & Spink, 2002) and thus shy away from teaching the subject. Therefore, the present study looks at the extent to which primary school teachers adopt and use STS materials when exposed to a focused, professional development experience.

Aim of the Study

The aim of the study was to examine the effect of introducing an STS approach on the knowledge and classroom practice of eight primary school teachers in Swaziland. The study seeks to answer the following research questions:

(1) How do teachers respond to the introduction of an STS approach to teaching science?
(2) How might the teachers' understanding and use of this approach be characterised?
(3) What are the implications of the observed teacher change for curriculum implementation?

Literature Review

Models of Teacher Change

Teacher change is a desirable objective and is essential for the successful implementation of new curricula. Many attempts at curriculum change have been superficial, due to a lack of understanding of the extent of teacher change required, as well as of how this change occurs (Rogan & Grayson, 2003). This is a particular problem in developing countries, where transmission teaching is the norm. For example, during the implementation of a new curriculum in South Africa, Rogan and Aldous (2005) observed a tendency for teachers to retain most of the practices of the old curriculum, but to attach new jargon to these practices.

Rogan and Grayson (2003) introduce a model of curriculum implementation, which makes allowance for the diversity of levels of different schools and teachers in a shared system. They introduce the concept of a 'Zone of Feasible Implementation', or ZFI, which is established through a combination of three constructs: 'Profile of Implementation', which includes classroom interaction, science practical work, science in society and assessment; 'Capacity to Innovate', which considers physical resources, teacher factors, learner factors, school ecology and management; and 'Outside Support', which refers to types of encouragement and support, dominant change force evoked by agency, monitoring mechanisms and accountability. A vital element of each of these constructs is the teacher. All constructs are achievable at different levels, depending on the context. Rogan and Grayson have argued that implementation is only successful if it proceeds just ahead of actual practice, and that the zone will be different for schools in different situations.

One of the most widely used models of teacher change is the Concerns-based Adoption Model (CBAM). According to Anderson (1997), the model is concerned with measuring, describing and explaining the process of change teachers experience when they attempt to change instructional practices, and how that process is affected by interventions from facilitators. Hord (1987), another CBAM team member, notes that many innovations in science education fail to achieve the desired impact, due to the tendency to treat change as an event, rather than as a process. Thus, innovations are prematurely abandoned when they fail to yield immediate changes in classroom practice. She also argues that change is often described in global terms, revealing little about day-to-day classroom processes. The CBAM is now a well-established diagnostic tool for managing change (see http://www.sedl.org/cbam/ online), with explanatory videos, manuals and tools. The model consists of three diagnostic dimensions, namely

- Innovation Configurations: a clear picture of what constitutes high-quality implementation;
- Stages of Concern (SoC): enables the identification of stakeholders' attitudes and beliefs towards a new initiative; and
- Levels of Use (LoU): determine how well stakeholders are using a programme, ranging from non-use to advanced use.

These components combine to produce the model as summarised in Figure 1.

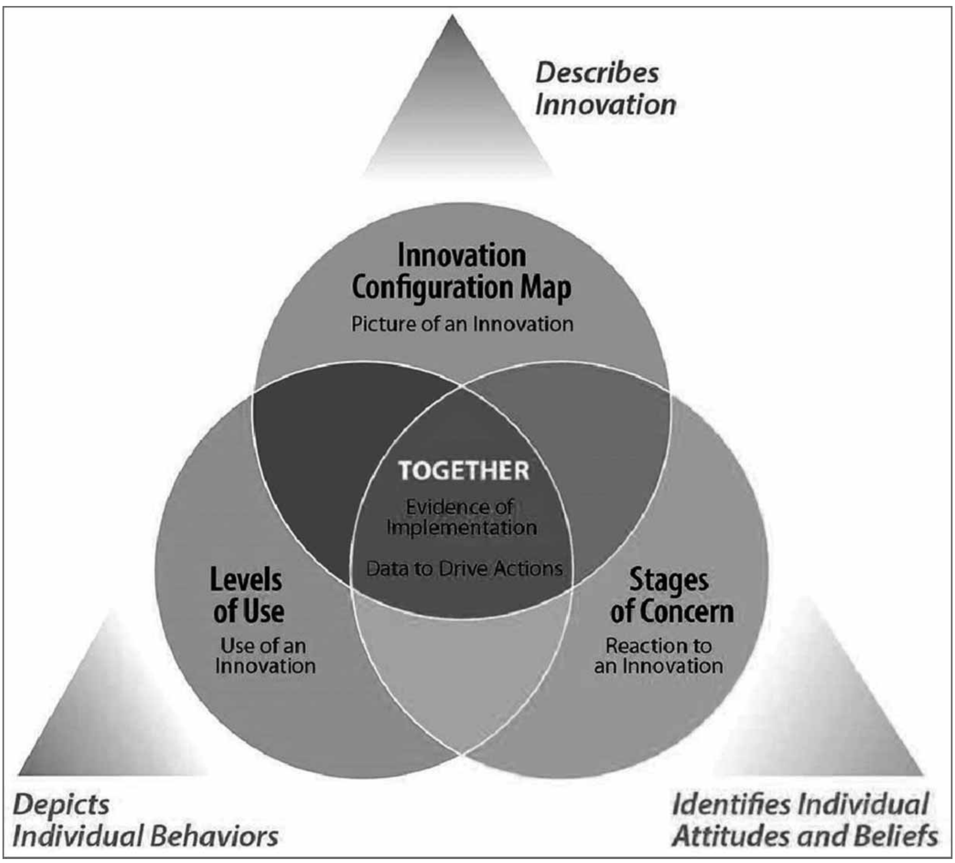

Figure 1. CBAM model (http://www.sedl.org/cbam/)

The CBAM recognises that innovations will not always be implemented in the same way; so the innovation configuration takes the form of a checklist, identifying the various configurations of use.

The 'SoC' are identified as 'unconcerned', 'informational', 'personal', 'management', 'consequence', 'collaboration' and 'refocusing'. The model suggests that a teacher's progress from becoming aware of an innovation, but taking no action (unconcerned), to having enough interest to merely gather information (informational); using the innovation but worrying about their adequacy to do it (personal); worrying about managing the task (management); worrying about how it will affect learners (consequence); worrying about sharing with other colleagues (collaboration); and finally worrying about sufficiently 'making it their own' so as to generalise its use (refocusing).

The LoU are specified as: 'non-use'; 'orientation'; 'preparation' (all classified as levels of non-use, though the last two may refer to teachers who are planning to use the innovation); 'mechanical' (the lowest level of use); followed by 'routine' which describes an established pattern of use where most teachers are said to settle. Higher levels reached are: 'refinement'; 'integration'; and finally 'renewal'. These higher levels imply an engagement with the innovation, which allows collaboration and modification. As with the SoC, Anderson (1997) points out that the LoU represents a possible—not a necessary—developmental progression. One assumption that seems to be implicit in the theory is that the teachers understand the proposed change, in order that they are concerned about it, or use it.

The mechanical approach is familiar in Africa (See Rogan, 2004), where Hord (1987) describes the mechanical user as one who is still experimenting with the approach, and trying to make it work. Mechanical use describes an approach where teachers are merely trying to survive and to make the innovation easier for themselves. Hord regards this as a necessary and inevitable stage, but one that can be shortened with facilitation. This is superseded by a higher routine level, where the teacher is able to use the teaching materials, but is not yet able to adopt or modify them for own use. Many teachers in Africa who lack in-depth understanding of the innovation, will stay at a mechanical level, lacking the realisation of the potential of the approach (Rogan & Aldous, 2005).

Another well-known model of teacher change is that described by Guskey (2002), where focus is given to the fact that teachers are motivated primarily by changes that they believe will lead to improvement in student learning outcomes. Until teachers observe such changes, there will be no change in their beliefs and attitudes. The implication of Guskey's model is that change is a difficult process, as teachers are reluctant to adopt practices until they are certain they can make them work. A further implication is that follow-up and support is even more crucial than initial training in an innovation. In the current study, follow-up visits were an essential component of the innovation.

Stein and Wang (1988) present a model, which draws on Guskey's foregrounding of teachers' concern for better student outcomes, but their model also includes the construct of self-efficacy (Bandura, 1977). A common concern in the case of primary school teachers is their content knowledge (Warren & Ogonowski, 1998). When teachers lack confidence in their content knowledge, this can affect their self-efficacy (Newton, Leonard, Evans, & Eastburn, 2012).

STS Approaches

STS approaches, which include context-based approaches, have been used in science education for the last 40 years, initially with the expectation that it will result in improved scientific understanding (Bennett et al., 2007). In a comprehensive review, Pedretti and Nazir (2011) outline the history of STS approaches since their inception (now expanded to science, society, technology and environment, STSE), and provide insight into the different understandings of the approach that exist in the literature, their varying ideological orientations and the ways the different approaches play out in practice. They contrast their approach with earlier attempts by Aikenhead (2003) to classify various approaches. While Aikenhead explored the different ways in which STS may be integrated into the curriculum, Pedretti and Nazir were more concerned with the philosophical underpinnings and characteristics of the approach. They identify and characterise six currents in STSE education: application/design; historical; logical reasoning; value centred; sociocultural; and socio-ecojustice currents. All approaches differ substantially from a traditional science content-centred approach and would require a substantial change in teaching approach for teachers who are used to transmission teaching approaches (Yager, 1992). Each approach is underpinned by a characteristic focus.

The approach used in this study is the closest to the logical reasoning approach, which focuses on understanding issues and decision-making through the consideration of empirical evidence. Typically, the approach involves the use of real-life issues and problems in Science teaching, usually as the starting point of the learning process (Bennett et al., 2007), and could also be described as a contextualised approach.

An important element in the development of STS(E) materials is related to the affective domain, where it is assumed that by making Science more relevant and meaningful to students, they will feel more positive about the subject, as they see the importance of what they are studying (Aikenhead, 2006; Bennett et al., 2007). Although Bennett et al. (2007) report that most research on STS approaches has been carried out at the secondary school level, Yager and Akcay (2008) make the point that the approach is ideally suited for middle school, where there is less demand on students for examination-type tasks, and consequently more freedom in the curriculum for activity-based work.

The approach used in this study was described as STS, rather than STS(E), since there was no inclusion of the environment in the intervention, and the data collection and conceptualisation of the study predated the move towards STS(E). Our STS approach includes three specific aspects of teaching, namely contextualisation, application and investigation (Lubben et al., 1995). Contextualisation is defined as in Lubben, Campbell, & Dlamini (1996), often known as an applications-based approach. Contexts are presented as stories, comics or student activities, which are then used for application. On other occasions, the teaching begins with a consideration of a common application of a scientific principle, such as a motor, which is then used to teach the concept of electromagnetism. Investigation is built in, usually as a separate activity to investigate the cause of a phenomenon, but also to investigate variables in a situation, such as comparing the amount of gas in carbonated soft drinks. The model used for designing lessons is similar to that employed by Stolk et al. (2011), where students are first introduced to a practical problem related to a context, increasing students' curiosity and creating a 'need to know'. Next, the students study the concepts and finally carry out an enquiry project, applying the concepts studied. Lubben et al. (1996) makes the point that class observations show contextualised learning to only be successful if teaching styles move away from traditional teacher-centred approaches. Given that much primary teaching in Swaziland is teacher centred, an introduction of any innovation of this nature would require a substantial change in teacher practice. Thus, there are significant challenges to face in assisting teachers to apply STS approaches. Teachers need confidence and require empowerment (Stolk et al., 2011), so as to develop a willingness to discuss controversial issues in their science classes (McGinnis & Simmons, 1999). This is an essential element of STS education and needs to be taken into consideration in the design of any intervention.

Methods and Methodology

Design of the Study

The study aimed to obtain in-depth information about the way in which teachers adopt an innovation in a situation involving teachers of differing qualification and experience, in diverse teaching situations. The questions asked in this study required qualitative answers, suggesting an approach in the naturalistic paradigm (Opie, 2004). Qualitative data collection techniques and analysis were utilised for this reason. We were investigating teachers' understanding and use of a new approach, suggesting ethnographic data collection techniques, as explained below.

The teachers were introduced to and used an STS teaching approach through workshops and classroom support. We were aware that the need to involve teachers in lesson design was necessary for successful reforms (Stolk et al., 2011). Thus, we used an approach similar to that of the Salters science (Bennett & Lubben, 2006), and later, the Matsapa lessons in Swaziland (Lubben et al., 1995), which provided a local example of a similar successful approach. Both the Salters and Matsapa approaches used workshops where teachers designed draft lessons, which were later refined by the development team. Two features of this approach are salient here. First, the design of the materials and the professional development of the teachers were conducted as parallel processes. Second, existing curriculum materials in use were adapted to reflect the STS approach.

The overall design resulted in two three-day workshops, followed by a supported five-week-long, school-based implementation period (referred to as 'the intervention'), as described below.

The first workshop was held early in the year, when the materials were at a draft stage, and involved explicit input of a subset of the teachers towards the writing of materials. The workshop strategy was adapted from that used for the development of the package developed during the 'Matsapa Project' (Lubben et al., 1995), referred to above, and its choice was influenced by its reported effect on teachers' skill and commitment (Lubben et al., 1995), although in practice, teacher-generated lessons required considerable refinement. The second workshop was held three months later, to introduce participating teachers to the materials, which had now been refined to incorporate the input of teachers from the first workshop. The emphasis in the second workshop was on induction to the new materials, mostly through peer teaching.

An existing Grade 6 unit, entitled 'Matter and Energy', was adapted for this study. The new unit consisted of five lessons, using the STS approach. Table 1 provides a summary of the lessons taught and the approaches used.

Teachers taught the unit over a five-week period. Throughout this period, each teacher was visited with three purposes in mind: to support teachers, to observe the lessons and to collect data. Of 40 lessons taught (5 per teacher), 30 were observed. Additional visits were also made to provide support, to conduct interviews and to administer questionnaires (see below). In total, 58 visits were made to the 8 teachers. Support was provided through discussions, answering of questions and offering of suggestions, where necessary. The teachers found many aspects of the lessons new

Table 1. Lesson summary for the unit

Lesson topic and content	Context type	Learner activities	Aspect of STS approach used
1. States of matter	Learner activity using materials from the environment	Present homework, make charts, write story identifying and characterising states of matter	Contextualisation
2. Physical Changes in common substances	Contextualised story	Experiment on melting, dissolving and expansion, speculate on a story, complete table, write letter	Contextualisation
3. Making new substances (chemical change)	Contextualised story	Experiment investigating Rusting, write letter	Investigation
4. Acids and alkalis	Adventure using cartoon characters	Examine evidence from experiments on soil acidity, test substances	Contextualisation and investigation
5. Conductors in complete circuits	Problem situation on incomplete electric circuit	Construction of torch, identify relevant science to solve problem.	Application

to them, for example, the decentralising of classroom activities; the commencement of a lesson with an application; speculation on issues raised in contexts, and problem-solving using previously learnt concepts.

Participants in the Study

It was decided to focus the study on Grade 6 teachers, as this is the most senior grade in the school system unimpeded by public examinations (taken in Grade 7). Since learners start with English as a medium of instruction in Grade 5, it was thought that by Grade 6, the learners would have developed a greater level of facility with the language of instruction to focus on the science. The teachers were a convenience sample selected through an initial approach to nearby schools. Despite the fact that the teachers were recruited as volunteers, it became clear later that some teachers had agreed to participate due to pressure from their principals, who had been responsible for committing their schools to the study. Teachers were given the option to withdraw but opted to remain in the study. The background and participation profile of the eight participating teachers is presented in Table 2.

It can be seen from Table 2 that apart from Susan, all teachers had well over 10 years of teaching experience. Most had trained prior to 1986, when the entry norm for primary teacher training was 10 years of schooling and a two-year certificate. Pam had subsequently upgraded her qualifications. Susan and Tim, the only teachers with less than 15 years' experience, had trained under the post-1986 system of 12 years of schooling and three-year diploma.

Data Collection and Analysis

Data sources relevant to this paper were journal notes of workshop activities, field notes from lesson observations and two teacher questionnaires at different points in

Table 2. Background of participating teachers[a]

Teacher	Qualification	Teaching Experience (years)
Grace	Grade10 plus PTC	20
Lungi	Grade12 plus PTC	16
Mavis	Grade12 plus PTC	14
Pam	Grade12 plus PTC upgraded to PTD	28
Sonto	Grade10 plus PTC	28
Susan	Grade12 plus PTD	5
Thuli	Grade10 plus PTC	29
Tim	Grade 12 plus PTD	13

Note: PTC, Primary Teaching Certificate; PTD, Primary Teaching Diploma.

[a]Both PTC and PTD qualifications were offered by local teacher training colleges. PTC was a two-year qualification, which required a minimum Grade 10 for entry, and was later replaced by the three-year PTD, requiring Grade 12 for entry.

the study. These methods were decided on, as they could provide a large amount of individual data from the teachers in a reasonably short amount of time. Though time-consuming, the interviews were added to improve trustworthiness by triangulation (Opie, 2004).

Two questionnaires were adapted from Lubben et al. (1995), to obtain information on teacher background, including teacher conceptions of science teaching, and teacher understanding of the STS approach pre- and post-intervention, as well as their response to the new approach, addressing research Questions 1 and 2 for this paper. The questionnaires (pre- and post-workshop) were piloted at earlier teacher workshops elsewhere, and changes were made mainly in terms of language and brevity. Apart from basic demographic data and general questions about their views on teaching the unit of matter and energy, the questionnaires sought teachers' views on good science teaching. There were two key questions eliciting understanding of contextualisation, which asked teachers to react to lesson scenarios using contextualised and non-contextualised approaches, and to identify salient differences in the approaches. The first key question asked whether the lesson scenarios were examples of contextualisation, application or investigation, and the second was more open ended, asking them how they would use a given picture of an everyday situation in their teaching. Journal notes were also taken during the workshops to assess how the teachers' understanding of the approach was developing, supplemented by audio recordings. The journal notes from the workshop were checked with a participant observer.

Field notes constituted the primary data source to establish the level of use of the innovation. Throughout the implementation period, field notes were kept of all visits and lesson observations. These were written up for analysis with the assistance of audio recordings.

Table 3 provides a summary of the process.

The above models, particularly the CBAM, informed the development of typologies that emerged in the data analysis below, but the concerns in this study differed somewhat from any one of the models considered above. Rather, a synthesis of the ideas, coupled with the context and focus of the study, informed the final typologies

Table 3. Summary of the data collection

Activity	Instrument and main purpose	Purpose
Workshops	Questionnaires: pre-workshop: personal details, teaching history, views about teaching Pre- and post-workshop: test understanding of STS approach Journal notes: record of workshop proceeding	• Establish understanding of the approach • Obtain contextual information
Implementation	Field notes: record of meetings and lesson observations	• Further data on understanding of the approach • Establish levels of use

that evolved. The participants in the study were primary teachers, with levels of training that would have been regarded as less than adequate in the developed world. Thus, their levels of content and methodology preparation would be lower than the primary teachers in the Newton et al. (2012) study, for example. Our focus was first on their understanding of the approach and then on the use, rather than on the SoC, as outlined in the CBAM model. Hence, we evolved typologies of understanding of the approach. The LoU also required modification, as the first three stages in the CBAM model actually refer to non-use, and all teachers in this study did begin to implement the innovation. Finally, our data only allowed for two categories above mechanical use.

Most of the data were recorded in the form of text (interview transcripts, responses to questionnaires and field notes). These were divided into segments, and coded using open codes, which could later be clustered into umbrella codes, which linked to some of the categories in the CBAM theory outlined above. This manner of coding can be described as a combination of grounded theory (Strauss & Corbin, 1990), with codes informed by prior theoretical understanding.

The teachers in the study began by answering questionnaires that probed their ability to distinguish between STS and traditional approaches (understanding), and ended by teaching lessons designed to use these approaches (use). Hence, it was possible to assess both understanding and use. The initial coding was done by the second author, and validated by the first author, on a sample of the data. The coding of questionnaires, interview transcripts and field notes were counter-checked by independent researchers, with knowledge of the context and the field.

Understanding of the STS teaching approach was assessed in three broad areas, forming coding categories as follows, drawing primarily from the questionnaires and workshop journal notes:

(A) Understanding of the concepts of contextualisation, application and investigation—ability to categorise a lesson from a description;
(B) Extent of description of use of contexts (e.g. linking contexts with lessons, promoting scientific skills development, promotion of higher order skills, level and quality of teacher-pupil interaction); and
(C) Ability to develop an STS lesson.

Each of these indicators was assessed and allocated to one of the five hierarchical levels of understanding of the STS approach shown below:

- *Unawareness*: Inability to perceive difference between lessons using STS and traditional approaches (neither A, B nor C).
- *Perception*: Understanding of the difference in approach between using STS and traditional approaches (part of A only).
- *Utilisation*: Ability to describe appropriately the use of the STS approach (A and part of B);
- *Personalisation*: Ability to incorporate the innovation to personal teaching (A and B).

- *Production*: Ability to develop contextualised lessons (not explored in this study) (A, B and C).

The levels of understanding elucidated above are necessary but not sufficient conditions for teachers' use of the STS approach in practice.

LoU were assessed during the implementation period, where teachers' use of the STS approach was deduced primarily from field notes taken during classroom observations and visits to the teachers. The analysis of LoU of contexts and classroom interactions produced a distinct typology of use. These were coded 1-4 on two criteria, level of use of the contexts, and classroom interactions. Descriptors of progress in each of these indicators coded from the data are shown in Table 4.

From the analysis, using these descriptors, five LoU were developed as follows: dropouts; strugglers; domesticators (similar to mechanical use in the CBAM model); succeeders (similar to routine use in the CBAM model); and innovators (aligned to refinement in the CBAM model). Table 5 presents how these were linked to the criteria in Table 4. For example, succeeders were coded 3 for both type of use of contexts and classroom interactions, while domesticators remained at code 1 for type of use, but were coded 2 or 3 on classroom interactions.

Findings

Data collected through the study showed non-uniform development in understanding among the teachers. The levels of comprehension above characterised the development of the teachers as they learnt the approach.

Analysis of the responses to the pre-workshop questionnaires revealed that all teachers started with no knowledge of contextualisation. For example, when asked 'do you teach science lessons based on learners' experiences?' Sonto said:

> I would give clear picture of what must be done in the lesson, and have a lot of [*sic*] practicals. (Sonto, pre-workshop questionnaire)

Table 4. Descriptors of attainment of criteria

Code	Level of use of contexts	Classroom interactions
1	Not/partially used	Teacher talk dominates. Learner talk restricted to one word or chorus answers
2	Used by rote	Teacher talk dominates. Learners talk encouraged but limited
3	Used appropriately, but restricted to provided materials	Balance between teacher and learner talk. Groups used superficially. Learners give more extended answers
4	Discussion and explanation linked to prior knowledge and lesson with appropriate follow-up questions. Materials modified to suit context	Balance between teacher and learner talk. Group work dominates, learner argumentation observed

Table 5. Link between descriptors and typology of use

Level of use	Type of use of contexts	Classroom interactions
Dropouts	1	1
Strugglers	1,2	1
Domesticators	1	2,3
Succeeders	3	3
Innovators	4	4

This response represents typical answers from all eight teachers, prior to the introduction of the concept of contextualisation. By the end of the induction workshop, their understanding had shifted considerably. Evidence of this development is presented, with respect to the various levels of comprehension below.

Unawareness: The inability to perceive the difference between STS and traditional approaches. Initial evidence of understanding of the STS approach became evident when teachers were asked to compare exemplar descriptions of lessons using the lesson scenarios in the questionnaire. It was evident that initially, teachers could not 'see' any difference in approach between a contextualised lesson and a corresponding traditional one. Tim and Mavis fell into this category. For example, when asked to point out differences between a traditional and contextualised lesson:

> As they discussed [. . .] they covered a number of differences and similarities, all of which related to the content and resources; [. . .] the layout and the approach was not mentioned. (Workshop JN)

After a lengthy discussion, followed by an illustration of the use of the contexts, the difference in approach appeared to make sense to some teachers. However, Tim and Mavis remained in the unawareness category throughout the intervention. For example, when asked to describe contextualisation in the pre- and post-workshop questionnaires, Tim responded as follows:

> Let the learners experience the states of matter like liquid to a gas state [*sic*]. (Tim, post-workshop questionnaire)

Both Tim and Mavis were considered to be capable teachers, yet they gave responses that showed indistinct identification of contextualisation.

Perception: Refers to the ability to recognise the difference in approach between a contextualised lesson and a traditional lesson. The second level of understanding was shown by those teachers who realised that the innovation was different from their usual approach. Sonto, Lungi and Thuli showed a clear sense of recognition that the STS approach was different from the standard approach, yet they were unclear about what the difference entailed. Thus, they never progressed beyond this level of understanding. For example, towards the end of the workshop, Thuli asked:

> [So, to clarify:] contextualisation is when you tell the story and application is when you now teach the lesson, and an investigation is when they do the experiments and make the observations? (JN)

Utilisation: The ability to appropriately describe the use of the STS approach. Those teachers who progressed beyond the perception level showed an understanding of how to use the approach, and could respond to application-type questions in the questionnaires. At this level, teachers were able to say what the approach entailed, and could, given examples of lessons, correctly identify a contextualised lesson. Grace reached this level of understanding. While commenting on how successful she was with contextualisation, Grace said:

> It was the way of introducing the lesson [*sic*]. You read a story related to the lesson and then ask questions, which learners respond to, instead of plunging straight into [*sic*] the lesson. (Grace FN)

Grace understood how to use the approach. She referred to the different processes involved in contextualisation, such as asking questions related to the context (speculation). Though she appeared unaware of the specific terminology, she was certain that she had done as expected.

Personalisation: The ability to adapt the innovation to personal teaching. The next level describes those teachers who personalised their understanding of the approach. Only Susan and Pam reached this level. They made comments that reflected sufficient understanding to apply the approach in other lessons. For example:

> Pupils have to bring materials from their society and use them for investigation in class as well as leading with a story which leaves them with a problem [. . .] pupils listen and later discover that there is science [. . .]. (Susan, FN)

Teachers in this category understood what the approach entailed, and were able to use it to approach other lessons, and were thereby able to be considered to have reached a level of personalisation. This is the highest level of understanding that was reached in this study.

Typology of Level of Use of the STS Approach

Dropouts: participants who withdrew from the intervention. Thuli gave up after teaching only one lesson. During that one lesson, her teaching consisted of verbatim instruction from the teachers' guide, and she was troubled when not able to finish the lesson. Although she did not explicitly state that she was withdrawing, it was not possible to observe her teaching a second time, despite attempts to fix appointments. She probably found it easier to withdraw from the project, without explicitly saying so. She was thus classified as having dropped out.

Strugglers: participants who used the approach, but struggled or used it by rote. Sonto and Lungi continued to use the STS approach, though they were uncertain about it.

Although they followed the teacher's guide closely, they showed no understanding of what they were doing. Both teachers made a genuine attempt to move away from their usual teaching approach. However, their lack of understanding limited their use of the innovation as shown below:

> [Having read the context story and shown rusted steel wool…]
>
> In our lesson today we are going to investigate the causes of rusting. Later I will tell you the reasons for rusting […] let us think of the causes of rusting. […] look at the booklet' and she reads from it
>
> [Sonto shows clear signs of not understanding the booklet, and the learners appear to be just as confused as her. She assigned learners to bring steel wool for the next class, and after class, she asked me what to do with the steel wool]. (Sonto, FN)

Given that Sonto and Lungi recognised differences between the teaching approaches, but had not understood the innovation sufficiently, (see above) they were unable to use it effectively. This level of use is potentially more damaging than no change at all, because teachers had abandoned their familiar methods, but were not yet able to use the innovation as intended (Hord, 1987). The teacher is still struggling with knowing what to do. It is, however, possible that further support on the use of the approach might convert teachers at this stage into succeeders.

Domesticators: participants who taught successfully, but adapted innovation to their normal teaching approach. As mentioned above, Tim and Mavis were classified in the unawareness category, in terms of their understanding the innovation. Consequently, they used the new materials by making no changes to their normal teaching practice. The innovation made no real impression on them, as shown by the extract below:

> [The teacher had written the topic on the board]
>
> Things change. Can anyone mention how things change? […] How does an ice cube look when it is taken from the refrigerator? Did it look like this? [Holding up an already melting ice cube] […].
>
> [The teacher writes 'melt' on the board and the lesson continues] […] then we are going to read the story on page 2 of your booklet.
>
> [A learner starts reading and Mavis begins telling the same story, stopping midway to ask:]
>
> What do you think she did with the ice block? […] What happened to the ice block? Students: 'Melted'.
>
> [The teacher then moved on to demonstrate. The questions read by the teacher were part of the materials]. (Mavis, FN)

These teachers only used the contexts as a support for the lesson's flow. This tendency continued throughout the implementation period. Tim and Mavis used the innovation to reinforce their own ideas about teaching. They showed confidence, and an ability to handle standard lessons, therefore they themselves probably saw no reason to change what they were doing (Fullan, 1992).

Succeeders: participants who successfully used the innovation as intended but dependent on support materials. Grace brought the contextualised lessons to life. However, she relied heavily on the written materials, and was unable to show creativity and variation as shown below:

> [After introducing chemical changes and illustrating using some objects:]
>
> ...now we are going to read the story about chemical changes...remember making new substances...how was the steel wool? What was wrong with it? [Students respond:] 'Rusted.'
>
> [Grace then showed a clean nail and said:]
>
> Before the nail rusted how did it look?
>
> [Grace also showed covered and uncovered steel wool:]
>
> We are going to investigate what caused the steel wool to rust. We are going to investigate, we are going to work like scientists...now let us go back to Mr. Mabuza's store. His business is about to fail, people will not buy the nails, because there is a problem. What would have [caused] the nails and steel wool to rust? (Grace, FN)

This ability to use the context as intended, in raising an awareness of a problem and the need to solve it, showed a good understanding of this aspect of the lessons. However, the appropriate use appeared to be restricted to the lessons exactly as written.

Innovators: participants who understood the innovation and were able to vary its use as needed. Two teachers, Pam and Susan reached this level. They were able to interact with the innovation, selecting what was appropriate, and rearranging the order of presentation to suit their classrooms. The following quote illustrates the way in which Pam managed the innovation.

> Some learners had read some comics given to them, and she asked them to tell the story to the rest of the class:
>
> List the things which the children in the magazine were investigating [learners list a number of things]
>
> What else were the characters looking for? What did they find?
>
> Pam then allowed a number of learners to make their contributions, encouraging learners to observe one another. The learners together debated about who had caught the thief in one of the comic book narratives. (FN, Pam)

Most of these questions were not in the support materials. Pam went beyond the use of materials as given to her, and restructured them to fit her class. Pam later said:

> I am excited about this approach because it brought life to my class. My learners also like it. Before, we did not do much practical work, because the administration does not buy any materials. Every material we use is brought by the learners from home. We use what we can. I will do the same [when it comes time for] the next topic. (Pam FN)

Similarly, Susan allowed learners to explore contexts in a variety of ways. They role-played the investigation from the comic book materials. She also shared ideas with other interested teachers, suggesting mutual support, with ideas beyond those mentioned in the materials. On later visits, Susan was found to display projects she had given learners according to her own initiative to raise their interest and had adapted her approach to other grades she was teaching.

Teachers' Development in Typology of Use

The teachers' development is summarised in Table 6, using criteria from Tables 4 and 5.

When comparing the typology of use with the progression of understanding, it was found that as expected, the better teacher understanding was linked to more versatile use, though the relationship was not simple. Table 7 presents the relationship.

From Table 7 it can be seen that teachers at middle levels of understanding, like Sonto, Thuli and Lungi, actually showed a lower level of use than those who remained at the unawareness level. They were able to see the difference in approach, and consequently made an attempt to use it. The result was a series of lessons that were unintelligible to the learners, and uncomfortable for the teachers; resulting in the inevitable conclusion that they would have been better off using a more familiar

Table 6. Development in typology of use

Name	Type of use	Classroom interactions	Comments
Lungi	1	1	*Struggler*: confused using the approach
Mavis, Tim	1	3	*Domesticator*: never used STS approaches. Use of the materials reinforced usual teaching
Sonto	2	1	*Struggler:* difficulty understanding the STS approach, experienced confusion in teaching
Thuli	2	1	*Dropout*: remained bound to materials, dropped out after teaching one lesson
Grace	3	3	Progressed from *domesticator* to *succeeder*
Pam	4	4	*Innovator*: learnt while teaching. Blended approach into her normal teaching
Susan	4	4	Began with uncertainty but learnt quickly, was eventually excited about new approach, went from *domesticator* to *succeeder* to *innovator*

Table 7. Understanding and use of STS approach

Teacher	Level of understanding	Final level of use
Pam	Personalisation	Innovator
Susan	Personalisation	Innovator
Grace	Utilisation	Succeeder
Sonto	Perception	Struggler
Lungi	Perception	Struggler
Thuli	Perception	Dropout
Mavis	Unawareness	Domesticator
Tim	Unawareness	Domesticator

approach. Mavis and Tim adapted the materials to their style of teaching, and reported themselves to be happy with what they believed to be the new approach.

It is possible that with further support, Sonto and Lungi may have been able to change their teaching approach. However, Thuli's experience shows that an unhappy experience with the materials may lead both of them to abandon the innovation. Meanwhile, for Mavis and Tim, intervention might only be beneficial after they are provided with more extensive learning opportunities. On the other end of the scale, Grace, Susan and Pam eventually displayed a higher level of understanding of the approach, and were able to make use of it in a satisfactory way. Only Pam and Susan became innovators. That is, teachers who had appropriated the innovation showed versatility in its use. This finding is not surprising, given that Hord (1987) has found that when teachers cease to be concerned with whether or not they are doing as they are meant to, they focus on making an approach work. A minimum level of understanding appears to be a prerequisite for the teacher to effect a change in practice and to maintain equilibrium in the classroom.

Discussion

To answer research Question 1, we consider what changes occur when teachers are introduced to an innovation. The study identified changes in understanding and use. With regard to understanding, two issues arise: first, whether or not it is necessary to acquire complete understanding of an approach prior to implementation; and second, how teachers acquire their understanding.

Findings from this as well as other studies show that teachers who acquired a higher level of understanding of the approach, did so primarily during the supported implementation. The workshops provided a valuable orientation to the approach, but for the teachers who rose above the level of recognition, the implementation played a major role in their development. For example, Grace progressed from merely a verbal understanding at the workshop, to the added ability to contextualise effectively during the implementation period. However, some initial understanding proves important. Working in a well-resourced environment, Henderson (2003) found insufficient understanding of teaching approaches may be a barrier to successful implementation. His study found this understanding necessarily occurred if teachers recognised the difference between the new and old approaches, and that realisation of differences is a vital precursor to the beginning of understanding. In this study too, the workshop activity that was aimed at pointing out differences between contextualised and other approaches, seemed to assist understanding.

However, Johnson, Monk, and Hodges (2000) suggest that while understanding is necessary, it is not a sufficient condition for teacher change. They maintain that there are many other objective conditions in developing country environments, such as large classes, the shortage of basic resources, as well as community and school resistance to change that militate against change, even in the teachers with the necessary understanding and skill.

In response to the second issue, some teachers acquired the necessary understanding during implementation, but it was expected that involvement in lesson development would impact understanding and motivation, where only limited success was achieved.

Rogan and Grayson (2003) suggest that change may occur if it takes place within the ZFI, though some studies have suggested that real change takes time (Banilower, Heck, & Weiss, 2007; Johnson et al., 2000). Johnson et al. (2000) point to a slow, incremental change, while Rogan and Grayson (2003) emphasise the importance of the context within which the teachers work, along with their current abilities. Thus, this study suggests that teacher change is incremental, and that different levels of understanding may be reached, at different rates by different teachers.

An important element of Rogan and Grayson's framework (2003) is the construct of 'capacity to support innovation', which includes the level of qualification of the teacher. Prior to 1986, it was possible for primary teachers in Swaziland to qualify with only 10 years of schooling and 2 years of training. Teachers qualified in this way are limited in their ability to adapt to change. Pam and Susan each possessed 12 years of schooling and a three-year diploma. The other six teachers in the study (with the exception of Tim) can be described as under-qualified in terms of the sophistication required to implement a contextualised approach effectively. Another pertinent factor is that of experience. Susan, the teacher with the least experience progressed to the highest level of use, while Sonto, who had 28 years of experience, made the least headway. Sufficient academic background appears, however, to be the greater determinant, as both Susan and Pam not only had 12 years of schooling (while Sonto had only 10), but both also held a higher qualification.

In response to research Question 2 regarding the characterisation of the understanding and use of the approach, two hierarchies were developed and were found to be useful in describing the progressions in understanding and use of innovation. Since five of the eight teachers in the study were constrained by their limited qualifications, it is not surprising that five of these teachers did not rise above the level of perception in their understanding of innovation and hence, either struggled to use the approach, domesticated it or dropped out. The typology of use hierarchy starts from dropouts, proceeding to strugglers, then to 'succeeders', and then on to innovators. Without more intensive learning opportunities for the teachers, it would be difficult to improve their understanding of the innovation, which is a notable prerequisite for successful implementation. An approach using facilitated professional learning communities, such as that used in Pedretti and Bellomo (2013), suggests a way forward, but even here, the process was reported to be complex, and the importance of strong facilitation was highlighted. In the context of a developing country, where both human and physical resources are constrained, the engagement would need to be extended and well facilitated.

In answer to Question 3 regarding the implications of the observed teacher change for curriculum implementation, Fullan (1992) suggests a reciprocal relationship between behaviour and belief change, which often leads to difficulties in implementation, referred to as an 'implementation dip', where an attempt at implementation may be accompanied by a drop in performance. If these difficulties are not ridden out, sustainable change remains difficult, underscoring the need for adequate time required for long-term change. In this regard, the current study shows one source of the implementation dip to be teachers who start at the perception level of understanding, who then require further support at the implementation stage so as to move to a more effective level of understanding. Above the recognition level, teachers were more effective users of the approach. As pointed out by Rogan and Grayson (2003), the implementation of a new curriculum approach needs to match the level of development of the teachers and schools, suggesting that the level of intervention needs to occur within the ZFI of the school and its teachers.

Conclusion

Teachers in this study benefitted from an intervention designed to provide them with initial recognition of curriculum change. However, the extent to which this recognition is achieved may depend on individual contexts, including environmental factors. Similarly, the ability to progress depended on the initial capacity of the teacher to develop. The observation that much of the understanding developed during the implementation period, suggests that further development of understanding is possible, with extended school-based support.

The study produced five levels of understanding, beginning with unawareness of the characteristics of the innovation, ranging to the highest level reached in this study, where teachers are able to personalise the approach. There is a suggestion of a further level of understanding, termed production, which would enable teachers to create their own contextualised lessons not reached during the study, even though some of the teachers were involved in lesson production. As stated above, this was not a surprise, as the creation of lessons has been found to be a challenge in more sophisticated contexts (Stolk et al., 2011). The intervention in this study was a limited one in terms of both size and scope. With a higher level of facilitation and a longer period of implementation, it might have been possible to achieve a greater degree of success.

There was also a progression in level of use, and as in Hord's stages, there were dropouts. Although only one teacher in this study fell into this category, it was in a context of supported use, and with less support, the number of teachers in this category may be greater. When dropouts outnumber implementers, then any innovation is in jeopardy. The second level, that of strugglers, is equally threatening to an innovation, as it leads to innovation dips as mentioned above, and ultimately to further dropouts. The next level, domesticators, leads to superficial change. The level thereafter, succeeders, would show some success in implementation, but would find it difficult to apply the approach in new contexts. The highest level of use was among the innovators. In this case, teachers were able to select from different sources to teach a contextualised lesson. Their learners experience a variety of activities with a variety of materials. Teachers at this level were also found to share their experiences with other teachers, making the presence of the innovation felt. Finally, the study showed that there is a close relationship between understanding, and use of new approaches. Only those who reach at least the utilisation level succeeded in implementing the approach.

If contextualised approaches are to be implemented effectively, methods need to be found to reach teachers with interventions that improve their awareness of the nature of the innovation, and how it differs from current practice. More sustained studies are also needed to isolate factors within the implementation structure that enhance understanding. Such studies would identify the nature of the difficulties experienced by teachers at the different levels. Finally, more research is needed to establish whether all teachers can reach sufficient understanding of innovations. The results of such research would be of great value to policy-makers, teachers and curriculum developers. Furthermore, awareness of the existence of these progressions could lead to the development of diagnostic tools, and teachers identified at the higher levels of understanding might be recruited to assist those struggling in structured learning communities.

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No potential conflict of interest was reported by the authors.

References

Aikenhead, G. S. (2003). STS education: A rose by any other name. In R. Cross (Ed.), *A vision for science education: Responding to the work of Peter J. Fensham* (pp. 59–75). New York, NY: Routledge Falmer.

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*. New York, NY: Teachers College Press.

Anderson, R. D., Anderson, B. L., Varank-Martin, M. A., Romagnano, L., Bielenberg, J., Flory, M.. . .Whitworth, J. (1994). *Issues of curriculum reform in science, mathematics and higher-order thinking across the disciplines*. Washington, DC: US Government Printing Office.

Anderson, S. E. (1997). Understanding teacher change: Revisiting the concerns based adoption model. *Curriculum Inquiry*, *27*(3), 331–367. doi:10.1111/0362-6784.00057

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

Banilower, E. R., Heck, D. J., & Weiss, I. R. (2007). Can professional development make the vision of the standards a reality? The impact of the national science foundation's local systemic change through teacher enhancement initiative. *Journal of Research in Science Teaching*, *44*, 375–395.

Bennett, J., & Lubben, F. (2006). Context-based chemistry: The Salters approach. *International Journal of Science Education*, *28*(9), 999–1015.

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education*, *91*, 347–370.

Fullan, M. (1992). *Successful school improvement*. Maidenhead: Open University Press.

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice*, *8*(3/4), 381–391. doi:10.1080 /13540600210000051 2

Henderson, C. (2003). *Easier said than done: A case study of instructional change under the best of circumstances*. Paper presented at the Physics Education Research Conference, Madison, WI.

Hewson, P. W., Kahle, J. B., Scantlebury, K., & Davies, D. (2001). Equitable Science education in urban middle schools: Do reform efforts make a difference? *Journal of Research in Science Teaching*, *38*, 1130–1144.

Hord, S. (1987). *Evaluating educational innovation*. London: Croom Helm.

Johnson, S. D., Monk, M., & Hodges, M. (2000). Teacher development and change in South Africa: A critique of the appropriateness of transfer of northern/western practice. *Compare*, *30*(2), 179–192.

Lubben, F., Campbell, B., & Dlamini, B. (1995). *In-service support for a technological approach to science education*. Education Research. Serial no. 16. Retrieved November 28, 2003, from http://ageconsearch.umn.edu/bitstream/12850/1/er950016.pdf

Lubben, F., Campbell, B., & Dlamini, B. (1996). Contextualizing science teaching in Swaziland: Some student reactions. *International Journal of Science Education*, *18*(3), 311–320.

McGinnis, J. R., & Simmons, P. (1999). Teachers' perspectives of teaching science–technology–society in local cultures: A sociocultural analysis. *Science Education*, *83*, 179–211.

Newton, K. J., Leonard, J., Evans, B. R., & Eastburn, J. A. (2012). Preservice elementary teachers' mathematics content knowledge and teacher efficacy. *School Science and Mathematics*, *112*(5), 289–299.

Opie, C. (2004). *Doing educational research: A guide to first time researchers*. London: Sage.

Pedretti, E., & Bellomo, K. (2013). A time for change: Advocating for STSE education through professional learning communities. *Canadian Journal of Science, Mathematics and Technology Education*, *13*(4), 415–437.

Pedretti, E., & Nazir, J. (2011). Currents in STSE education: Mapping a complex field, 40 years on. *Science Education*, *95*(4), 601–626.

Putsoa, B., & Dlamini, C. (Eds.). (2005). *Science in everyday life* (Vol. 1). Manzini: Macmillan Boleswa.

Rogan, J. (2004). Out of the frying pan…? Case studies of the implementation of curriculum 2005 in some science classrooms. *African Journal of Research in Mathematics, Science and Technology Education*, *8*(2), 165–179.

Rogan, J., & Aldous, C. (2005). Relationships between the constructs of a theory of curriculum implementation. *Journal of Research in Science Teaching*, *42*(3), 313–336.

Rogan, J., & Grayson, D. (2003). Towards a theory of curriculum implementation with particular reference to science education in developing countries. *International Journal of Science Education*, *25*(10), 1171–1204.

Shallcross, S., & Spink, S. (2002). How primary trainee teachers perceive the development of their own scientific knowledge: Links between confidence, content and competence? *International Journal of Science Education*, *24*(12), 1293–1312.

Stein, M. K., & Wang, M. C. (1988). Teacher development and school improvement: The process of teacher change. *Teaching and Teacher Education*, *4*(2), 171–187.

Stolk, M. J., de Jong, O., Bulte, A., & Pilot, A. (2011). Exploring a framework for professional development in curriculum innovation: Empowering teachers for designing context-based chemistry education. *Research in Science Education*, *41*, 369–388.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

Stronkhorst, R., & Akker, J. v. d. (2006). Effects of in-service education on improving science teaching in Swaziland. *International Journal of Science Education*, *28*(15), 1771–1794.

Tsai, C. (2001). A review and discussion of epistemological commitments, metacognition, and critical thinking with suggestions on their enhancement in internet-assisted chemistry classrooms. *Journal of Chemical Education*, *78*(7), 970–974.

Warren, B., & Ogonowski, M. (1998). *From knowledge to knowing: An inquiry into teacher learning in science*. Newton, MA: Education Development Center.

Yager, R. E. (1992). The features of Science-Technology-Society that make it a major reform in science education. *Science Educator*, *1*(1), 5–11.

Yager, R. E., & Akcay, H. (2008). Comparison of student learning outcomes in middle school science classes with an STS approach and a typical textbook dominated approach. *RMLE Online*, *31*(7). Retrieved from http://www.nmsa.org/Publications/RMLEOnline/tabid/426/Default.aspx

Yager, R. E., & Weld, J. E. (1999). Scope, sequence and coordination: The Iowa project, a national reform effort in the USA. *International Journal of Science Education*, *21*(2), 169–194.