“It’s More Than Knowing the Science”:
A Case Study in Elementary Science Curriculum Review

Brian Lewthwaite
University of Manitoba

Abstract

This research exercise, employing an action research model for school-wide science curriculum improvement, explores the factors influencing science program delivery in a multicultural elementary school in Northwestern Canada. Using a validated science program delivery evaluation tool, the Science Curriculum Implementation Questionnaire (SCIQ), as a foundation for data collection, staff discussion and collaborative decision-making, a school embarks on a self-review process to, first of all, identify factors influencing science program delivery and, secondly, identify strategies for improvement of science delivery. Implications of this self-review process on science program delivery improvement are discussed, especially within the context of the adequacy of teacher pedagogical content knowledge within a multicultural context. As well, recognizing the limitations of the SCIQ within the context of study, modifications to the SCIQ are also presented.

Key Words

elementary (primary) science delivery, evaluation instrument, professional science knowledge

Introduction

Despite the significant improvement in the delivery of science programs at the elementary school level in some nations over the past two decades (Harlen, 1997; Frost, 1997), there is continued acknowledgement of the complex amalgam of factors impeding effective elementary science delivery in many educational jurisdictions (Mulholland & Wallace, 1996). Although, historically, a list of commonly cited extrinsic or environmental factors (time constraints, equipment, space and facilities) is suggested to impede science program delivery at the primary level, research efforts (Appleton & Kindt, 1999; Appleton & Symington, 1996; Gustafson, Guilbert & MacDonald, 2002; Harlen, 1997; Lewthwaite, Stableford & Fisher, 2001; Rowell & Gustafson, 1993) have also affirmed intrinsic factors such as teacher beliefs, knowledge, attitudes and competencies and less salient extrinsic aspects such as the priority placed on science as a curriculum area, as further critical agents to successful science program delivery.
Because of the many complex and interrelated factors identified as impediments to effective science program delivery, it is not surprising that some authors regard primary science education internationally to be in a parlous state (Mulholland & Wallace, 1996). This perilous, ‘hard to put a finger on it’ situation arises from the fact that, as Fullan (1992) affirms, the success of curriculum implementation and improvement efforts is influenced by several system elements and that no one single factor can be targeted alone to effect change in curriculum delivery. Fullan (1993) asserts that curriculum interventions tend to leave the basic policies and practices of schools unchanged. These interventions tend to ignore the fact that changes in the core culture of teaching require major transformation in the culture of the school. Often the primary school culture is typified by ambivalence towards science education (Harlen, Holroyd & Byrne, 1995; Tilgner, 1990; Weiss, Matti & Smith, 1994). For this reason, curriculum reviews, policy changes, and overall reformation in the arena of primary science education are largely seen as empty rhetoric. International efforts indicate that although primary science curriculum reviews and reform efforts are admirable, the outcome of the reviews is primarily limited to increased teacher awareness and not teacher change (Harlen, 1997).

Stewart and Prebble (1985) suggest that effective curriculum implementation and improvement come from a systematic, sustained effort at changing learning conditions in the classroom and other internal conditions within the school. Understanding the context in which change is to occur is at the heart of school development (Stewart & Prebble, 1993). This understanding is established through the gathering of high-quality information that provides insight into the forces at work within the school. In turn, this information becomes the foundation from which discussion, reflection and deliberate focused change can begin (Stewart & Prebble, 1993). Because of the role this foundational data can have in informing strategic school development, the diagnosis or systematic assessment of the school environment is seen as an essential means by which the forces that are at work in a school impeding or contributing to curriculum implementation can be identified.

Stewart and Prebble (1993) describe a variety of strategies for systematic data gathering, one of which is the use of validated standard instruments. The study and
systematic analyses of learning environments and educational climates using standard instruments is a well-developed area of educational research (Fraser, 1994; Fraser & Tobin, 1998). The systematic analysis is conducted through the use of measurement instruments that are able to assess the participants’ perceptions of the various attributes of the educational environment. For schools not wishing to invest the considerable amount of time and energy needed to complete more formalized and extensive school reviews, the use of standard instruments is seen as a time efficient, accurate but somewhat superficial means of understanding the forces at work within the educational context (Stewart & Prebble, 1993). When the data collected from the instrument application are coupled with narrative, they provide a foundation for increasing collective knowledge and understanding of organizational procedures and problems (Stewart & Prebble, 1985). As stated by Owens (1995), the employment of the good diagnostic tool becomes the starting point for the articulation of a reasonable prognosis.

**Intent and Context of the Study**

The primary purpose of this research exercise was to use a validated curriculum delivery evaluation tool as a vehicle for focused and collaborative science delivery improvement at an urban elementary (Year 1-6) school in northwestern Canada. The study explores strategies for curriculum delivery improvement, through collaborative discussion and decision-making based on the collection of data, and thus subscribes to an action research model of school improvement. Furthermore, the study involves the application in a Canadian context of a curriculum delivery evaluation instrument developed, validated and used extensively in New Zealand (Edmonds & Lewthwaite, 2002; Gulliver & Lewthwaite, 2002; Payne & Lewthwaite, 2002). Since the application exercise assesses how well the questionnaire measures the breadth and depth of factors influencing a content area i.e. science curriculum delivery in a multicultural school where all teachers teach science as part of their professional duties, this instrument application study is also regarded an assessment of the questionnaire’s content validity (Gay, 1996).
Northwest School (pseudonym) is a Year 1-6 school in an urban community in Canada. The school has a full-time teaching staff of fourteen with a very low staff turnover rate and a student enrolment of 244. The student population is largely First Nations. 46% of the student population identifies themselves as of First Nations decent. A further 16% of the population is represented by other ethnic minorities such as East Indian, Pakistani and Filipino. All full-time teachers, aside from two subject specialist teachers in French and Native Language Studies, are expected to teach science as a part of their regular classroom program. Provincial legislation regulates the amount of time devoted to the teaching of science. In response to this requirement, Northwest School policy document states that students will be provided with a balanced and comprehensive education that addresses the requirements of the provincial curriculum (Northwest School, 2000). Each grade level in the school uses a text as a foundational resource in the teaching of science. The text series is in alignment with the provincial science teaching requirements and is acknowledged by the teaching staff as an appropriate resource in terms of its readability and the learning opportunities it encourages. Most teachers supplement this central resource with a variety of other activities, most of which have been developed from acquired resources by teachers in the school. The school has one senior teacher designated as the curriculum leader for science. Every two years, she is required to conduct a curriculum review and report her findings to staff.

In order to determine the content validity in a Canadian context of a primary science delivery evaluation instrument developed in New Zealand, the author approached a northern school district superintendent to seek approval to conduct the research exercise in a representative elementary school in the region. Knowing that each school in the school district conducted these evaluations, it was suggested by the superintendent that Northwest School was a representative school in terms of size and cultural representation, in particular in regards to the First Nation population. During the initial consultation amongst the principal, science curriculum leader and author it was decided that the research exercise would follow a model of school improvement suggested by Stewart and Prebble (1993) and would focus on (1) ascertaining the factors influencing science program delivery at Northwest School through the use of an evaluation instrument and
follow-up discussion; (2) identifying and implementing focused strategies for improvement (with outside professional development support if necessary) based on collaborative staff decisions; (3) re-evaluating the effectiveness of the focused strategies after a cycle of focused improvement; and, finally, (4) further identifying and implementing strategies for improvement on the basis of the re-evaluation. The outcomes of research foci 3 and 4 listed above at time of writing have not been completed and are thus not reported in this paper.

Methodology

A comprehensive, validated instrument, the *Science Curriculum Implementation Questionnaire* (SCIQ) (Lewthwaite, 2001) was used in the evaluation of factors influencing science program delivery at Northwest School. The SCIQ is a 7-scale, forty-nine-item questionnaire that provides accurate information concerning the factors influencing science program delivery at the classroom and school level in schools where the teaching of science is a regular part of a teacher’s teaching duties. The scales have been developed with the intent of gauging staff perceptions on a 1 (Strongly Disagree) to 5 (Strongly Agree) scale in areas that are identified as major impediments to science program delivery (Lewthwaite, 2000). Four of the scales pertain to the school environment. These environmental or extrinsic scales include Resource Adequacy; Time; School Ethos; and Professional Support. The remaining three scales relate to teacher personal attributes. These intrinsic factors include Professional Science Knowledge; Professional Adequacy; and Professional Interest and Motivation. Many of the scales address many aspects pertaining to the same dimension. As an example, the Professional Science Knowledge scale measures teacher perceptions of the adequacy of their subject matter, pedagogical knowledge and, to a lesser extent, pedagogical content knowledge. Examples of items from the Professional Science Knowledge scale include:

*Teachers at this school have a secure science knowledge base upon which to base their teaching of science.*

and
Teachers at this school have a sound knowledge of strategies known to be effective for the teaching of science.

The SCIQ exists in two forms, Actual and Preferred, which are both completed by the entire school teaching staff. The Actual form indicates the way things are and the Preferred indicates how teachers would prefer things to be. By completing the Actual and Preferred forms discrepancies between the actual and preferred environment are evident. The information is processed by following a specified, straight-forward procedure of analysis. Mean (average) calculations can be performed to identify general trends in perceptions for each of the scale and, if desired, each item and standard deviations can be calculated to determine the degree of consistency amongst respondents for each scale and again, if desired, each item.

All teachers, aside from the French and Native Language Studies teachers, completed both the Actual and Preferred versions of the questionnaire. Mean and standard deviation results for each of the scales were calculated and served as a foundation for staff discussion and collaborative decision-making regarding action for strategic curriculum development. The staff discussion ensuing from the data presentation, facilitated by the author, were audio taped, transcribed and authenticated as a literal transcription by the principal and science teaching staff. The study endeavours to, first of all, understand a phenomenon (i.e. the factors influencing science program delivery) and is thus interpretivist in nature. (Erickson, 1986). What was learned throughout this study was informed by the experience of the researcher through the collection of qualitative and quantitative data and authentication and interpretation of these data by the participant teachers. As well, the study is guided by an action research methodology as it intends to use an iterative cycle of planning, action, observation and reflection to improve on current situations (Hopkins, 1985).
Results and Discussion

Tables 1 and 2 that follow present the foundation data collected from the SCIQ application of the Actual and Preferred forms. As well, the information is presented graphically in Figure 1.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Actual Mean Results</th>
<th>SCIQ Actual Standard Deviations</th>
<th>Preferred Mean Results</th>
<th>SCIQ Preferred Standard Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Adequacy</td>
<td>4.2</td>
<td>0.2</td>
<td>4.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Time</td>
<td>4.0</td>
<td>0.3</td>
<td>4.3</td>
<td>0.2</td>
</tr>
<tr>
<td>School Ethos</td>
<td>3.9</td>
<td>0.3</td>
<td>4.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Professional Support</td>
<td>3.5</td>
<td>0.5</td>
<td>3.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Professional Adequacy</td>
<td>3.6</td>
<td>0.3</td>
<td>4.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Professional Science</td>
<td>3.2</td>
<td>0.7</td>
<td>4.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Professional Attitudes</td>
<td>4.0</td>
<td>0.3</td>
<td>4.4</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 1: Science Curriculum Implementation Actual and Preferred Profiles for Northwest School (n=12)

Figure 1: Science Curriculum Implementation Actual and Preferred Profile for Northwest School
Following a model of school development endorsed by Stewart and Prebble (1985) whereby data collection and presentation become the foundation for discussion and collaborative decision-making, the intent of the SCIQ and meanings of the scales and collected data were explained by the author to the staff. Some of the general trends identified from the data presented to staff included:

The results from the Actual SCIQ indicate that teachers at Northwest School perceive that the school is adequately resourced for the teaching of science. Not only is the school well resourced, the school’s facilities and system of managing these resources positively influences the teaching of science (Table 1: mean score 4.2). A standard deviation score of 0.2 indicates that this positive perception is consistent amongst staff. The Preferred SCIQ results indicate that the perceived improvements desired in the resourcing of science are minimal (Table 1: mean score 4.4).

Teachers at Northwest School perceive that the school places a high priority on science as a curriculum area and that this is reflected in the administrative decisions and actions of the school. The overall school ethos is seen to be contributing to the teaching of science (Table 1: mean score 3.9). The standard deviation score of 0.3 indicates that this positive perception is quite consistent amongst staff. Again, the Preferred SCIQ results indicate that teachers desire a slight improvement in the priority placed on science as a curriculum area (Table 1: mean score 4.2).

Teachers at Northwest School have reasonably positive perceptions of their ability to teach science. Teachers see themselves to be adequately prepared to teach science and are reasonably confident science teachers. They have positive perceptions of themselves as regards their ability to teach science. The mean score of 3.6 and standard deviation of 0.3 indicate that this perception is quite positive and consistent amongst staff (Table 1). Again, the Preferred SCIQ results indicate that teachers desire an improvement in their own capabilities as teachers of science (Table 1: mean score 4.2).

Teachers at Northwest School have neither strong nor weak perceptions of their professional science knowledge. Teachers see themselves as having neutral perceptions of the background knowledge necessary to teach science. Their knowledge of the subject and the strategies known for promoting effective learning are seen to be only adequate. The mean score of 3.2 and standard deviation of 0.7 suggests that this perception is not consistent amongst staff (Table 1). The Preferred SCIQ results indicate that teachers desire an improvement in their professional science knowledge (Table 1: mean score 4.4).
The staff were asked to comment on the accuracy of each scale and the general trends evidenced from these data. The discussion prompted many comments, primarily in the confirmation of the positive environmental or extrinsic aspects identified by the SCIQ.

Staff A: *So the two lines (referring to the graph: Figure 1) represent where we’re at in these areas and where we think we’d like to make improvements? If that’s the case I agree.*

Facilitator: *Why do you say that?*

Staff A: *It’s probably not just for science but I think overall we feel we have a very good hold on the delivery of subjects. We have put a lot of time into our teaching and getting the programs into shape.*

Staff B: *I’d agree. We have committed the past few years to the development of a coordinated school program, emphasizing good teaching, in all areas.*

Facilitator: *Any comments?*

Staff C: *There’s good support and leadership …we always have need for more resources but overall we’re well organized and supplied.*

Staff D: *In some areas more than others….. but we know things are done well here. There’s a commitment to being a good teaching school…I know we regarded well for this (good teaching).*

Principal: *For those of us that have been here for a while we know we give regard to the emphasis we have placed on providing good instruction to all grade levels and to support each other in achieving these goals (of offering good instruction).*

Staff discussion continued to identify the environmental factors that were contributing to effective science curriculum delivery. Staff identified that the success of the delivery was attributable to a variety of factors, all identified by the SCIQ (e.g. well-resourced; good management of resources; effective time management; professional, collegial and community support), and that most of these factors were largely influenced by a collective determination by the teaching staff and administration to provide instructional excellence in all curriculum areas, not just science. As asserted by Hall and Hord (1987), integral to this success was the role of the principal. The staff recognized that the principal was not only an effective school manager, but also a leader and catalyst for continued curriculum improvement (Fullan, 1992). It was he who ensured that the
school’s emphasis was on instructional quality and, by so doing, emphasized the importance of the school being adequately resourced and supported in the delivery of curricula. Staff discussion, fostered primarily by the principal, clearly identified the existence of a shared institutional value towards science as a valued curriculum area (Nias, Southworth, and Yeomans, 1989). Again, these aspects of curriculum priority and leadership endorsed by the principal and senior administration were identified by the SCIQ.

The author directed the discussion towards the teacher professional attribute or intrinsic factor data influencing science curriculum delivery. In particular, the discrepancy between the Actual and Preferred results for the Professional Adequacy and Professional Science Knowledge that had been identified by the SCIQ (Figure 1) were highlighted.

Staff D: *We probably have to give a bit more effort to science as a curriculum area but, again, we make this a priority.*

Staff E: *The resources we use give me the support I need to address the curriculum properly. I wouldn’t say I’m that comfortable with science but the resources and overall support give me the confidence I need. If I have a clear knowledge of what I’m expected to teach (from the curriculum) I’m o.k.*.

Facilitator: *And what about your attitude and interest in science and the teaching of science? The SCIQ results suggest that teacher attitude towards science is quite positive.*

Staff D: *Again, I think it’s good. The approach we take involves the students and they enjoy what we do. This has a positive effect on me and my teaching of science.*

Staff F: *I’d agree with what you have there.* (referring to the profiles). *As the profiles show we are both comfortable and interested in teaching science even though you might not feel totally on top of it*

Facilitator: *What do you mean by that – not totally on top of it?*

Staff F: *There’s a lot to know in science...just the amount you need to know.....and the ways to teach it meaningfully to students.*
Facilitator: *The content knowledge you mean and the ways to teach this knowledge?*

Staff F: *Yes, the knowledge that underpins the activities – first of all what you are expected to teach...knowing this and knowing what you would expect students to learn from the lessons...and how you go about the teaching. You’re always thinking about doing it better to get things across better.*

Staff A: …… *I just feel in teaching science that I want to help them to make better sense of things and I wish I had a better understanding of where they’re at – in terms of their experiences and backgrounds – then (if I knew) I’d be in a better position to direct my teaching....I know that for many of these students the way they view the world is largely developed through their upbringing and I’m afraid I’m not familiar with these (cultural) aspects.*

Staff G: *I feel the same….I feel comfortable with the science and the ways to teach purposely but, like Staff A I need to be more purposeful…. I feel comfortable with the science content but it’s more than knowing the science – It’s knowing about them. I feel really comfortable teaching in this setting (referring to being a European Canadian in a multicultural school). If I knew where their thinking was at, I’d be much better at helping them make connections in their learning.*

At this stage of the discussion, the author was aware that the concern about the potential culture clash (Aikenhead & Atsuji, 2000) experienced by students in science classrooms was a concern for only these two teachers. A follow-up interview with Staff A and G allowed them the opportunity to expand on their concerns about knowing about their learners. When asked to elaborate further on her knowing “more about their thinking”, Staff G commented that:

*We just taught a unit on feeding relationships, interdependence, trophic levels and ecological interrelationships in systems and I felt so... unknowledgeable about how some of my students were seeing these relationships. I just knew it wasn’t sitting well with some kids. We examined it from a pretty narrow perspective when I think of it compared to how some of the students may view such things. We discuss these things and they tend to be open about these things but I just need to be able to touch base with their thinking better.*

Similarly, Staff A commented:

*It’s not so important with some things like magnets and electricity but in the areas that have to do with the natural world; this is where I know I could be more purposeful in my teaching. I just don’t want to say this is the way it is when I*
know the way they see it is likely to be quite different (from what I am expected to teach).

Staff Teacher A and G acknowledged that it was possible and even likely that for many of their students, learning Western science is a cross-cultural event (Aikenhead, 2001). Their comments demonstrated their need to understand the students’ personal preconceptions based on an epistemology other than Western science and to further develop an approach to teaching that recognizes and values the different perspectives of their students. As Aikenhead and Otsuji (2000) and Lewthwaite (1992) identified, Staff A and G’s awareness of the potential culture clash experienced by students in the typical science classroom was an unorthodox concern for the teachers of Northwest School.

Although commonly cited personal attribute factors such as science teaching self-efficacy and science teaching interest and motivation are commonly cited impediments (Abell & Roth, 1992; Goodrum, Rennie, & Hackling, 2002; Harlen, 1977, 1988; Lewthwaite, 2000) to primary science delivery, teachers identified the multidimensional nature of professional science knowledge as further a critical dimension in the improved delivery of the science program at Northwest School. Teachers acknowledged that they required a complex knowledge base for teaching that consisted of a knowledge of effective science strategies, curriculum intentions, subject matter knowledge and, as well, a knowledge of learners, especially within the multicultural context of the school.

This complex knowledge base required for teaching has become of particular interest to science educators and policy makers both nationally (Gustafson, Guilbert, and MacDonald, 2002) and internationally (Appleton, 2003; Lewthwaite, Stableford & Fisher, 2001). Shulman (1986, 1987) identifies seven knowledge bases as necessary for effective teaching. These include: (1) content knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) pedagogical content knowledge, (5) knowledge of learners and their characteristics, (6) knowledge of educational contexts and (7) knowledge of educational ends, purposes and values. Of increasing concern to science educators is the role of pedagogical content knowledge as a unique knowledge base essential for effective science teaching. It addresses useful forms of representation,
analogies, illustrations, examples, explanations and demonstrations that make selected science phenomena comprehensible to others (Shulman, 1986). Essentially, it provides teachers with knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners (Shulman, 1986). It also places emphasis on developing an understanding of common pre-instructional views held by learners and how learners learn. The professional knowledge base of teachers provides the basis for the development of (children’s) personal engagement with the subject and helps to develop an understanding of the nature of the knowledge within the discipline. As Aikenhead (2001) asserts, teachers further require knowledge of their students’ worldviews and the ability to engage students in cultural negotiation through a cultural approach to teaching and learning. Clearly, some teachers, as evidenced in the comments emanating from this discussion, identified the need of this complex knowledge base from which to implement an effective program (Baker, 1994). Teachers are required to bring a dynamic knowledge of learners within concurrent understandings of the curriculum, of the subject and of the pedagogical content knowledge. All of these components are essential elements in the teaching process (Baker, 1994) and thus essential attributes to fostering effective science program delivery. Although the SCIQ contained items that addressed knowledge bases pertaining to pedagogical, subject matter and aspects of pedagogical content knowledge, it failed to identify teachers concern with knowledge of the curriculum and knowledge of learners, especially within the context of their cultural worldviews.

This staff discussion marked the end of the preliminary school self-review based on data collection and discussion and collective decision-making in the area of science program delivery. Although environmental factors such as school ethos, resource adequacy, time and professional support were seen to be factors contributing to effective science program delivery, intrinsic factors such as teacher professional knowledge were being identified as factors reducing the overall effectiveness of effective science program delivery. The staff discussion marked the end of the self-review process based on data collection and discussion. From there, the discussion as (Stewart & Prebble, 1985) suggest focused on collective decision-making in the area of science program delivery. Some staff recognized that they wanted to develop their professional science knowledge
base within specific content areas of the curriculum. Of particular importance to others was developing their understanding of common pre-instructional views of learners, especially within an acknowledgement of cultural worldviews, and effective strategies for teaching science within a cross-cultural context. As well, some teachers expressed a concern for improving their professional capabilities in several physical science concepts such as light, magnetism, forces and changes to matter. Decisions were made to negotiate an appropriate professional development program to address these complex concerns through a local teacher consultant.

Overall, the SCIQ served to be a purposeful evaluative tool in assisting Northwest School’s science curriculum delivery review process. It had served as an efficient and accurate means to gather staff perceptions of both the environmental and professional attribute factors influencing science program delivery. As well, it had served as a foundation for discussing and identifying areas of concern and strategies for science delivery improvement. The discussion that accompanied the data presentation was also instrumental in identifying shortcomings to the SCIQ as a diagnostic tool for identifying factors influencing science program delivery. In consequence to these shortcomings, two additional items pertaining to knowledge of the curriculum and knowledge of learners (Items 36 & 43 respectively) have been added to the Professional Science Knowledge scale of the SCIQ to address the complex knowledge base required by teachers in the teaching of science. The amended SCIQ is included in the Appendix.

**Summary**

Although this study affirms that various extrinsic factors associated with the school environment, in particular those relating to the role of the principal as an instructional leader, are major influences on effective science program delivery, intrinsic factors such as the complex teacher knowledge base, beliefs and attitudes teachers possess, also compound the complexity of the delivery process. As well, it shows that the systematic analysis of factors influencing curriculum delivery can be conducted through the use of measurement instruments. Understanding the context in which change is to
occur is at the heart of school development (Stewart & Prebble, 1993). This understanding is established through the gathering of high-quality information that provides insight into the forces at work within the school. For schools not wishing to invest the considerable amount of time and energy needed to complete more formalized and extensive school reviews, the use of standard instruments, such as the Science Curriculum Implementation Questionnaire, to collect foundational data when combined with narrative is advocated as a time efficient and accurate means of understanding the forces at work within the educational context and developing through collaborative discussion focused strategies for curriculum improvement.
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