Researching Effective Teaching and Learning in Science: The Science in Schools Research Project**

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Introduction

The Science in Schools Research Project is the largest school science initiative of its kind in Australia for decades (if not ever!). The Project is a major constituent of the Science in Schools initiatives developed by the Victorian Department of Education, Employment and Training (DEET). These are in turn part of the Victorian Government's Science and Technology strategy. The purpose of the Science in Schools (SiS) Research Project is to develop and trial a model for improving science teaching and learning in Victorian schools.

For the Deakin based research team, the SiS Research Project is a natural extension of insights we have gained into science teaching and learning in Victorian Schools, in a number of previous projects, and these also form part of the backdrop to the Project:

- A Science baseline study, undertaken for DEET in 1998 (Gough et al 1998, and the earlier preliminary study – see Gough, Matthews & Milne 1998), which probed the beliefs and practices of teachers across the state, concerning teaching and learning in science. This survey uncovered a number of issues related to teaching and learning in primary and secondary schools which are directly relevant to the current Project.

- A small scale DEET funded project, 'Science in the Middle School Years', carried out by Annette Gough and Russell Tytler, which provided insight into the different cultures of science classroom practice in primary and secondary schools, and possibilities for supporting improvement.

Findings from these studies have been fed directly into the SiS Research Project.

The Project brief was issued in mid 1999, and the tender awarded in late January 2000 to a consortium headed by the Consultancy and Development Unit in the Faculty of Education at Deakin University. Since then, the development of the theoretical framework has proceeded alongside the development of research instruments and testing materials. These materials, which were based on preliminary research as well as considerable work with the literature and consultation with science education experts, were in place by April 2000, and further refined for application in November 2000. In December 2000, the experience of working with schools, and the history of refinement and validation of the theoretical documents over the year, was brought together into a coherent set of theoretical and practical documents as the SiS Manual. This Manual, which has been updated again in November 2001, is being used for the schools involved in the ongoing Project, and will continue to be refined and validated. The SiS Research Project thus moved a long way during 2000, which represents the first phase of the ongoing Project, and during 2001 which has been the second phase of the Project.

During 2000, the Deakin based research team worked with 27 schools, in clusters of primary and secondary schools, in each region of the State to improve science teaching and learning in the schools. In 2001 the team worked with 126 schools in the nine regions across the state and in 2002 we will be working with 225 schools across the state. An outcome of this research has been the development of the **SiS School Improvement Model**. This model focuses on whole school improvement, and is a companion to the Early Years literacy and numeracy initiatives, and the Middle Years Research and Development (MYRAD) project. The model, represented diagrammatically in Appendix 1, draws on relevant research and best practice, including the Hill-Crevola General Design for Improving Learning Outcomes (1999).

The core of the model, and therefore the Project, consists of two major features:

- **The SiS Components**, which represent a framework of effective science teaching and learning; and
- **The SiS Strategy**, which is the process by which schools can improve their science teaching and learning.

The Model provides flexibility for schools and teachers to plan and implement initiatives based on the particular needs of the school, within an overall framework provided by the SiS Components. The SiS Model supports school science teams in identifying and capitalising on their strengths and experience, and drawing on the enthusiasm many students and their families have for science.

The Project is proceeding on a solid research base. During 2000, tests of student learning outcomes, attitudes and perceptions were used to monitor progress and outcomes, and this monitoring continued in 2001 and will continue into 2002.

While our procedures and instruments have been refined using the experience of teachers and schools in the first and second years, the essential nature of the Project remains the same. In each school, the Project is led by a SiS Coordinator (larger schools often support more than one coordinator) who is provided with time release to plan, to work with teachers in developing ideas and materials or in classrooms, to manage the change process, and to work with the central Deakin University based team and the DEET Regional Project Officers to implement the testing and monitoring programs. Each school has access to CRT funds to provide teachers of science with time release to plan, monitor and refine strategies, and to participate in PD.

The SiS Coordinator in each school is supported by a SiS Consultant (initially a member of the Deakin based research team but usually the DEET Regional Project Officer in 2001 and 2002) who visits regularly, provides input on a negotiated basis, and is in regular email contact. The Project assumes that the science team in the school is committed to improving science teaching and learning in the school, and that they will have the support of the school’s leadership team in doing this.

The aim of the Project is to produce, during this research phase, a well researched and refined Model, supported by resources, that will enable any school in Victoria to work towards the implementation of a program of quality teaching and learning in science.

A Project website (**www.scienceinschools.org**) describes the core features of the Project, acts as an archive for Project documents, and contains many examples of science teaching and learning practices that have been developed by the SiS schools, to illustrate the SiS Components.

Project Vision for School Science

The Project’s vision of the future for school science in Victoria:

- Science education in Victorian schools will encourage scientific literacy for all as well as providing a sound basis for students to take up specific science careers.

  All schools will recognise the importance of science in each student's education. All students will have opportunities to develop an interest in, enthusiasm for, and understanding of, science and its importance in daily life and in their future well being.

- Teachers will increasingly be enthusiastic and committed to the teaching of science. They will continue to develop their understanding of science and science teaching and become more effective in supporting student learning and conveying the richness and relevance of science ideas.

- Science classrooms will be innovative and active places, with strong links to the community and with a clear focus on supporting students to become autonomous thinkers and learners within a stimulating science environment.

Guiding principles

To promote this vision, the Project aims to:

- clarify the meaning of quality in school science teaching and learning, against which schools can effectively review their practice;

- provide processes for each school to clarify and assess the nature and purpose of its existing science program;

- provide the challenge, ideas and support for teachers to think and act outside existing frameworks of school science (to 'break set');

- respect the value of teacher knowledge and commitment as the keys to improvement; and

- respect and represent the local conditions in which schools operate.

The Research Program

The research program consists of three major elements:

- Identifying and validating components (the SiS Components) of effective science teaching and learning.

- Developing a model (the SiS School Improvement Model) and a strategy within this (the SiS Strategy) by which schools can improve science teaching and learning, and refining and validating this by charting the process of change within schools.

- Evaluating the effects of the Project on student learning and attitudes.

These elements are linked together to produce the research outcomes for the Project.

In a Project of this size the research plan is inevitably complex as there are both quantitative and qualitative features by which changes and outcomes are monitored. We have developed instruments to collect ***a variety of data types*****:**

- A mapping exercise to describe changes in the classroom practice of individual teachers against the SiS Components. This is the purpose of the component mapping interview.

- Large scale tests and questionnaires to measure changes in the science knowledge and attitudes of students during the life of the Project. In Phase 1 of the Project these were measured in both study schools and reference schools (which acted as a comparison). For the remainder of the Project validation of changes in student outcomes are being tracked using ‘growth curves’ of outcomes, hopefully picking up increasingly positive performance and attitudinal outcomes as time goes on.

- A set of interpretive case studies of schools and of teachers undergoing change, collected through SiS Consultant and teacher Progress Notes, and reports. These will be used to establish the types of changes that occur, and also to identify how best to support improvements in science teaching and learning.

- A small interview program which is collecting stories of student attitudes to science at different year levels.

- At the beginning of the Project, an interview schedule was developed and used with teachers and schools identified as representing effective practice, and these were used to generate and refine the SiS Components.

Research outcomes: out of these research instruments, then, we aim to:

- Identify how best to support schools in improving their science teaching and learning.

- Show that the SiS Strategy can lead to rich and innovative science teaching programs .

- Show that the SiS Strategy leads to improved science knowledge and attitudes.

- Show that quality classroom practice, as described by the SiS Components, leads to improved student outcomes.

- Identify which of the components are particularly important for improving student learning and attitudes.

- Develop support instruments and a strategy that will be able to be used by schools across Victoria to improve science teaching and learning.

Quantitative Data Collection

There were three major sources of data collected from the participating schools during 2000 and 2001, and these will continue to be collected in 2002.

Teacher component map: designed to monitor a teacher’s classroom practice. Characteristics and changes to practice will be linked with student learning and attitudes. The component map is based on the SiS Components which are discussed in the next section.

Student attitude survey: designed to probe students’ views about science and the teaching of science, and about preferred science teaching and learning practices in the classroom. This latter survey is based on an instrument used by the Accountability and Development Division of DEET. The survey was taken by students in Term 1, and again in Term 4 each year.

Student achievement tests: these are designed to cover a range of CSF levels in each strand. The testing will be either a web-based computer format, or by pencil and paper. For Phase 1 schools the tests occurred twice during 2000, in April and November, and twice during 2001 to give a number of data points for analysis of growth. Phase 2 schools were tested twice during 2001 and will be tested twice during 2002 as will Phase 3 schools.

In addition, a set of interpretive case studies of schools and of teachers undergoing change is being compiled and the small interview program for collecting stories of student attitudes to science at different year levels, started in 2000, will be continued in 2002. Some school stories have already been published in a special issue of the Science Teachers' Association of Victoria primary science journal *Let's Find Out* 18(1) and more will be published in *Lab Talk*, the Science Teachers' Association of Victoria secondary science journal.

Development of the theoretical framework

The SiS School Improvement Model

The Science in Schools Research Project is concerned with whole school change. The Science in Schools Improvement Model was developed during 2000 specifically to support practice in schools. It was designed to provide an overview of the school improvement process that the Project involves. It represents in summary form the relationship between the various factors and actions that have the potential to influence the outcomes of the improvement process. It can therefore act as a practical guide to decision making in schools, both at the whole school level and at the Key Learning Area (Science) level.

In the second half of 2000 the draft model was discussed with each of the 27 study school principals individually. Similar discussions have been undertaken with a sample of school principals in 2001. All responded positively to the model and agreed it had potential to be a useful planning tool from the school leadership perspective.

The model draws on relevant research and best practice, including the Concerns-Based Adoption Model (Hall and Hord, 2001), and the Hill-Crevola General Design for Improving Learning Outcomes (Hill and Crevola, 1999). It acknowledges the literature on school and teacher change, and professional development, and has been refined following research and development within the Science in Schools Research Project.

There are four main parts to the SiS Improvement Model:

- The External Environment
- Values, Beliefs and Understandings
- A flow chart of the implementation process
- Supporting Actions.

The External Environment

The various dimensions of the environments within which schools operate – social, educational, political, and so on - have both local and broader aspects. These all influence the operation of the school and its curriculum in some way. Four major sources of influence for Government schools are:

- the Accountability Framework, a means through which the Government, via DEET, monitors the effectiveness of schools in achieving their Charter goals

- the Curriculum and Standards Framework 11
- programs and priorities sponsored by DEET, and
- factors in the wider community, including labour market strategies, general economic conditions, local employment, and socio-economic factors.

Values, Beliefs and Understandings

Values, beliefs and understandings are major influencers of what individuals, groups and organisations (including schools) do and how they do it. Values and beliefs bearing on teaching and learning may be broad, for example, concerning truth and honesty, or more focussed, such as valuing science knowledge and the methods of science. Understandings affecting science teaching and learning include understanding the relationship between learning outcomes and what happens in the classroom, and understanding the benefits of scientific literacy to society and the individuals that comprise it.

Unless there are relevant values, beliefs and understandings held in common by those involved in planning and implementing a science curriculum, there can be no confidence that there will be coherence in what the students learn, or even that agreement on appropriate goals will be possible.

A Flow Chart of the Implementation Process

The flow chart shows, in simplified step form, the stages in producing improvement in science teaching and learning in a school (see Appendix 1).

Goal – The overall goal of the SiS Improvement Model is to improve teaching and learning in science, and through that, student learning outcomes.

Innovation –This is the essence of what is new that is being introduced. In the SiS Improvement Model, the innovation is the application in science teaching and learning of the SiS Components – the eight Components of Effective Classroom Science Practice.

Action Plan – This sets out specifically what the planning group in a school wants to achieve as a part of improving science in their school (based on the SiS Components), over what period, what is needed to do this, and how they will know when they get there. (How to develop an Action Plan is detailed in the SiS Research Project Manual.)

Implementation – the putting into practice of the Action Plan; it is, of course, connected with the Plan. The implementation process takes a period of time, as set out in the Action Plan. The Supporting Actions, outlined below, are essential contributors to the implementation process.

Outcomes – The main result of the effective introduction of the SiS Improvement Model in a school will be increases in student knowledge and skills, and changes in attitudes to science and science learning, produced through the achievement of the aims of the Action Plan. (There will also be other outcomes, for example, improved understandings and skills of the teachers involved.)

As aspects of the implementation of the Action Plan are completed, further versions of the Action Plan are developed to cover the next period (e.g., one, two, three years), and implemented on an ongoing basis. Through this approach, science teaching and learning continues to be reviewed, and to improve and develop.

Supporting Actions

Supporting Actions are actions that need to be taken, or that may be taken, to support the implementation process.

Arranging Organisational Support. Most of these are actions that need to be taken early in the process. Some concern fundamental organisational issues such as time-tabling and provision of appropriate space and teaching resources. It is essential that the science coordinator/science KLA leader and the Principal/Leadership Team work in unison in relation to these actions.

Professional Development. There is a wide range of professional development activities, formal and informal, that can be undertaken in order to develop or further develop the knowledge and skills necessary for effective implementation of the Action Plan. Preferably, these will be embedded in the school's Professional Development Plan.

Helping Individuals and Groups. This is often one of the most important (but easily overlooked) ways of assisting implementation. Individual and group encouragement, support and advice, often given informally, are relevant throughout the implementation process.

Monitoring and Evaluation. It is important to gather information about the progress of the Action Plan throughout the process, not only at the end. Effective monitoring can lead to improvements during the process and ensure that ineffective actions and processes are changed.

Reporting and Dissemination. Effective communication of information about a school's project to other members of the school community is important, as is dissemination of its progress amongst professional colleagues at other schools and elsewhere. Not infrequently, feedback from others can result in new insights and improvements.

It may not be feasible nor necessary to take all the actions listed in a particular period of time. However, some are essential. For example, it is essential that many of the actions in Box 1 of the diagram in Section A (Arranging Organisational Support) are taken very early in the introduction of the SiS Improvement Model. Those in Box 5 (Reporting and Dissemination) are more relevant later in the process. Others have more or less significance at various times during the process. The Supporting Actions boxes and their contents can be used as checklists of what actions should be taken, and what actions may be taken to assist implementation.

The Science in Schools Improvement Model is a model for continuing improvement of teaching and learning in science. Its design assumes that schools will develop and implement Action Plans based on the SiS Components. No matter what is the stage of a school's science development at the start of the process, an Action Plan can be developed so that improvement will continue to the lasting benefit of students.

Work is continuing in order to find ways in which the model in its current form can be improved from the point of view of a school. Feedback from schools is being sought during the course of the Project in 2001 and 2002. In addition, a more comprehensive paper concerning the origins of the model, its development, and its links with research and practice, is currently being developed.

The SiS Components: Describing effective science classroom practice

The SiS Components lie at the centre of the SiS Model. They represent a vision of science classrooms and teacher strategies, and student learning, that schools need to aim for.

The project team has drawn on a large body of research, and trends in science education internationally, as well as conducting our own research, to develop and validate the SiS Components

— a framework of quality teaching and learning in science. The Components aim to actively engage students in exploring science activities and significant ideas, and to tap into science relevant to their lives and linked to communities outside the school. It is the sort of science designed to produce the innovation and knowledge that the scientific and technology community has been calling for, and to enable and encourage students to engage with science ideas throughout their lives.

The SiS Components provide an explicit framework for teachers:

- A picture of what a classroom representing quality teaching and learning in science looks like.
- A set of guidelines for teachers in terms of strategies and actions.
- A set of principles against which teacher practice and curriculum planning can be audited.

The SiS Components were first developed out of interviews with twenty teachers who had been identified, through a combination of nomination and school results, as representing effective practice in science teaching. Out of these interviews, and subsequent workshop discussions, several common themes emerged, and these became the first version of the components. Subsequently, following further interviews both in Victoria and interstate, validation by experience and analysis within the SiS Research Project, and an extensive review of the international science education literature, they have been refined, and examples generated. It is likely that the Components may be further refined as the experiences of the Project and developments in the literature are further analysed.

In a practical sense, the SiS Components drive the component mapping exercise by which teachers monitor their classroom practice during the Project. They are also central in guiding the development of goals and initiatives in the school Action Plan. They are sufficiently flexible, however, to allow schools to focus on particular aspects of their needs, at different times during the Project.

During 2000 and 2001, the components were a powerful tool for ensuring that schools focussed on the central issues of teaching and learning rather than spending valuable time on such things as the reorganisation of equipment or the selection of a text book. While not unimportant, these are not central teaching and learning concerns.

The SiS Components have been developed using a number of sources:

- They draw on extensive research findings concerning conceptual change, often associated with constructivist, and metacognitive views of learning.
- They are consistent with the principles underlying the MYRAD project in Victoria, with a focus on student engagement, acknowledgment of student concerns, and a focus on conceptual challenge, meaningful learning and higher order thinking.
- They draw lessons from the extensive literature on student attitudes and motivation in science.
- They draw on contemporary concerns for promoting scientific literacy.

The SiS Components, concerning teachers, students and classrooms, are the core of the Science in Schools Strategy. The components were developed using interviews with teachers and schools with a reputation for effective practice, the research literature, and experience within the Project.

The components represent what a teacher needs to put in place in the classroom, to maximise the learning of all their students, and increase student engagement with and enjoyment of science.

The following is a list of the eight components. Details for each component, describing what it means in terms of classroom practice, what practices are contrary to the practice, and what examples of science teaching and learning illustrate each component are included in the 2001 Project Manual referred to earlier.

1. The learning environment encourages active engagement with ideas and evidence

2. Students are challenged to develop meaningful understandings

3. Science is linked with students' lives and interests

4. Students' individual learning needs are catered for

5. Assessment is embedded within the science learning strategy

6. The nature of science is represented in its various aspects

7. The classroom is linked with the broader community

8. Learning technologies are exploited for their learning potentialities

What has been achieved to date

A re-invigoration of science in schools

• Substantial change in school practice, evidenced by progress reports, interviews, consultant observations, anecdotes

• An increase in time allocation, and the nomination of Science as a charter priority in many primary schools

• Enthusiastic reports about SiS schools from RPOs

• Increased participation in PD and conferences by SiS schools

• Numerous articles on Science that have appeared in local newspapers across the State

• Enthusiastic presentations by SiS coordinators and teachers at conferences and in regional meetings.

Outcomes for primary schools

- A greater profile for science in the school and the local community
- A more coherent and thorough representation of science in the curriculum
- Increased resources and access to resources
- Improved attitudes, particularly confidence, concerning science teaching
- Evidence of changes to approach in teaching science

Outcomes for secondary schools

• Substantial changes in use of teaching and learning strategies consistent with the SiS components

• Increased dialogue in meetings and in the staffroom about teaching and learning science

• An increased sense of staff working together and recognising strengths and expertise of their colleagues

• Increased profile of science in the school and community

Measurable changes in schools, teachers and students

- Learning Improvement: (Phase 1&2 schools)

In primary schools, students taught by teachers who are implementing the research strategy are showing performance levels 8-12 months higher on average than students who are taught by teachers not implementing the research Strategy. These positive gains are beginning to flow through into secondary schools with year 7 students taught by teachers who are implementing the research strategy showing performance levels 3 months higher on average than students who are taught by teachers not implementing the research strategy.

• Teacher Practice: (Phase 1 schools)

In primary schools, 56% of teachers participating in the Project showed measurable improvement in their practice in the first six months of the Project. In secondary schools 46% of teachers showed the improvement.

• Student Attitudes to Science: (Phase 1&2 schools)

In both primary and secondary schools, students taught by teachers who are implementing the research strategy demonstrate significantly higher levels of enjoyment in Science learning.

Other results will be included in the presentation.

Indicators of successful uptake of SiS

• Quality of dialogue between staff, and coordinator

• Willingness of coordinator to introduce consultant to all staff, and show insight into the needs of individuals

• Degree of involvement / commitment of staff

• Enthusiasm of staff

• The care with which the innovations are monitored.

• The degree to which the innovations are embedded in the written curriculum.

• Reports of enthusiasm of students and of parents for what is happening

• Public enthusiasm for the Project, and a high profile through newsletters and local articles

• Intimate knowledge of and support for the Project by the school leadership team.

Where to in 2002?

As the Project enters its third year with the Phase 1 schools we are entering a different era. There is still a significant research component in order to meet the Project brief. However, we are also in to a 'roll out' mode with the aim of developing a sustainable model for the Strategy. So we need a new name!

We are also planning to 'drill deeper' into what is happening in classrooms and in the student achievement and attitude results.

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