Improving Middle Years Mathematics and Science

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Executive summary

The overall aim of the *Improving Middle Years Mathematics and Science* (IMYMS) project was to explore the explore the nature and significance of subject cultures in framing teacher and school practice in mathematics and science and to develop a middle years school improvement model that takes account of these subject cultures in influencing school and teacher change. The project also investigated ways in which effective pedagogies in mathematics and science can be monitored; and ways in which higher order learning outcomes in mathematics and science can be reliably assessed.

The project has worked with more than 30 schools in four clusters to support them in planning for and implementing change. A framework describing effective mathematics and science pedagogies was developed, and used as the basis for auditing procedures that track classroom practice. Instruments were developed and used to probe: teacher classroom practice; student perceptions of classroom practice and learning preferences; knowledge outcomes; reasoning in science and mathematics; understanding of the nature of science and mathematics; and performance skills in mathematics and science investigations. Data sources have also included questionnaire data, interviews, school reports and field notes. Video data was also collected and used for stimulated recall interviews concerning teacher beliefs and practices.

In order to support teachers and schools to improve their practice, the project team worked with cluster educators in each of the clusters, and with school coordinators, through a number of network meetings including an initial ‘leading change’ workshop, through cluster visits, and the provision of auditing and planning instruments supported by data analysis support. The nature of the subject cultures of, and effective pedagogies in, mathematics and science, was explored using interview data with effective teachers, literature exploration, interviews with project teachers to map characteristics of their practice, the team’s experience of the construction and analysis of achievement tests, a video and interview study of teachers of mathematics and science, and student perceptions data.

Project findings

Major findings from the project are grouped together under themes below.

Classroom practice in mathematics and science

- Generic formulations of pedagogy fail to capture important differences in the ways school mathematics and science are organised and taught. In mathematics there is a greater focus on specific and structured conceptual processes, compared to the greater representation of real life experience and experimentation in science. These differences flow from the particular disciplinary epistemologies and the particular subject cultures that have grown up around this.

- Differences in classroom practices between mathematics and science are evidenced in teacher practices and beliefs concerning that nature of support for students, the structuring of exploration and open investigative activities and the purposes of these, the linking with community in supporting learning, and assessment practices.

- Teachers of mathematics and science are committed to making the subjects relevant for students, but differ in their perceptions of relevance, and how they make the subject meaningful for students. The use of stories to illustrate subject matter relevance, exploration of familiar contexts, humanising stories, and representations of human endeavour in the discipline, are differently represented in mathematics and science. This creates potential problems for teachers teaching across subject boundaries.

- Teachers’ understanding of and commitment to their subject has important components that transcend simply knowing the subject matter, related to: being passionate about the subject and student learning, having a coherent sense of the subject, and identifying with the transformative nature of knowing the subject.

- Teachers experience difficulties in teaching across mathematics and science due to these different implied commitments to the discipline, to curriculum purposes, and to students.
- Student perceptions of classroom practice in mathematics and science, of effective learning activities, and of the importance of these subjects and their enjoyment, can also be related to aspects of subject culture. For instance, students regard mathematics as much more important than science, but find science much more enjoyable than mathematics.

Improvement in teaching and in learning

- Significant changes in teachers' practice were found across the life of the project through the use of the *IMYMS Components of Effective Teaching and Learning* which were developed to describe and monitor effective pedagogical practice in mathematics and science.
- Substantial student learning across a variety of conceptual areas in mathematics and science was demonstrated through an extensive program of assessment based on a model of student capability which focuses on different conceptual and affective dimensions.
- Through the use of the *IMYMS Change Model*, clusters engaged in a variety of innovative initiatives and demonstrated enhanced planning and pedagogical reflection.

Understanding the change process

- Contextual factors affecting school and teacher change were found to include:
  - tensions between a school and cluster focus, where it was found that organization across the cluster had some significant benefits, but also distracted some schools from framing change tailored to their own needs;
  - tensions between the cultures of secondary and primary schools, which interfered at times with developing a common vision and placed significant demands on cluster educators;
  - the leadership capability of cluster educators and school coordinators;
  - tensions between prior innovations and the IMYMS initiative, pointing to a need to carefully align new initiatives in schools with existing innovation programs;
  - rural and regional factors involving distance and school size and access to resources, with this being a serious impediment in some cases to the operation of the cluster and the provision of support for schools; and
  - consistency of project personnel, with significant change in staff in some clusters severely disrupting the progress of the project.

Ongoing analysis

There are further analyses in progress, exploring the large data sets relating to the student achievement and performance testing. Ongoing analysis is linking student outcomes to teacher practice as measured against the *IMYMS Components of Effective Teaching and Learning*. The model of student capability is being further explored.

Introduction

Improving Middle Years Mathematics and Science: The role of subject cultures in school and teacher change (IMYMS) was funded by an Australian Research Council Linkage Grant, with Industry Partner the Victorian Department of Education and Training.

The project team consisted of the Chief Investigators Russell Tytler, Susie Groves and Annette Gough; Australian Postgraduate Award Industry doctoral students Linda Darby and Christine Kakkinen; and Associate Investigator Brian Doig.

Aim of the IMYMS Project

The aim of the *Improving Middle Years Mathematics and Science* (IMYMS) project was to investigate the role of mathematics and science subject cultures in mediating change processes in the middle years of schooling. The project also investigated ways in which effective pedagogies in mathematics and science can be monitored; ways in which higher order learning outcomes in mathematics and science can be reliably assessed; links between teachers' pedagogies in mathematics and science; and the ways in which the cultures of teaching and learning of mathematics and science affect change processes.

The specific research questions addressed by the project were:

Q1 What are the specific characteristics of science and mathematics knowledge and learning that require differences in the formulation of effective teaching and learning?

Q2 How can effective pedagogies in mathematics and science be monitored reliably?

Q3 How can students' conceptual understandings in mathematics and science and ability to work mathematically and scientifically be assessed reliably?

Q4 What are the links between teachers' pedagogies in mathematics and science?

Q5 How do the cultures of teaching and learning of mathematics and science in primary and secondary schools affect the way change is constructed and pursued?

Background

The IMYMS project has its roots in the *Science in Schools* research project (SIS), which developed a successful strategy for improving teaching and learning science based on two major aspects: a framework for describing effective teaching and learning in science, and a strategic process for planning and implementing change – see, for example, Deakin (2003a). One of the main purposes of the project was to investigate the extent to which the SIS model can be used to improve the teaching and learning not only of middle school science, but also of mathematics.

The Deakin University team that developed SIS was also largely responsible for developing the Middle Years Pedagogy Research and Development (MYPRAD) project, which provided a strategy for planning and implementing pedagogical change across all subjects in the middle years of schooling.

While IMYMS was mainly based on the experiences from SIS, it also incorporated the middle years focus of MYPRAD as the time-frames for IMYMS and MYPRAD overlapped.

Overview of IMYMS

IMYMS was specifically developed for use by *Schools for Innovation and Excellence* clusters for planning and implementing change in the middle years of schooling. During term 3 of 2003, the Department of Education and Training called for expressions of interest for clusters to be involved in the IMYMS Project. Four clusters that had expressed interest were selected to make IMYMS their research focus. Each cluster has one or two secondary schools and a number of primary schools (see Appendix 1 for a list of clusters and schools within each cluster). These clusters had funding from the Victorian Innovation and Excellence initiative to employ a full time Cluster Coordinator to manage and guide middle years initiatives (of which IMYMS is one) and funds for teacher release for planning and professional development. In addition to the Cluster Coordinators, each participating school had an IMYMS School Coordinator to coordinate the collection of data and help support cluster and school initiatives.

IMYMS did not promote particular projects or initiatives, having been devised as a means by which clusters and schools could look carefully at their mathematics and science practice, identify key points for improvement, and develop a plan to initiate improvement and monitor change. It was nevertheless based on an explicit framework describing effective teaching and learning in middle years mathematics and science, and a change model that reflects contemporary understandings of teacher development and school reform. IMYMS was a research-based approach to planning and monitoring change, and schools and teachers were involved as participants in the research process.

The *IMYMS Change Model* is based on the School Innovation Model of SIS. It has two major features:

- *the IMYMS Components of Effective Teaching and Learning* – a framework of effective middle years teaching and learning in mathematics and science; and
- *the IMYMS Strategy* –a process by which schools and clusters can improve their teaching and learning in the middle years.

The IMYMS Strategy builds on the school improvement strategy used in the School Innovation in Science (SIS) initiative. The strategy worked through each school's middle years mathematics and science professional learning teams, assisting them to identify and capitalise on their strengths and experience. Based on extensive data collected by the IMYMS project from teachers and students, each cluster decided on foci for their Action Plans for improving their middle years mathematics and science programs. Data collected by the project team was analysed and returned to schools to be used as part of their planning and to fulfil the reporting requirements for the Schools for Innovation and Excellence initiative.

Timeline

The project was designed to commence in early July 2003, with the last six month of the year intended to be used to select and conduct initial meetings with the clusters and schools, and to develop the IMYMS components and support materials. This was followed by two years of cluster and school involvement (including school, cluster and project meetings; the collection of data from teachers, students, schools and clusters; action planning at the cluster and school level; and preliminary feedback to clusters and schools) and a six month analysis and evaluation phase. This analysis and evaluation phase had to be extended, given the initial late start to the project – due to the late approval of ARC Linkage Grants which resulted in the project only starting very late in 2003 – the late start and unanticipated three month breaks in the program for each of the doctoral students, and the complexity of some of the data analysis. At the time of writing this report, most of the analyses are complete, but some of the more complex analyses related to the test data and construction of a student capability model, associated with research question 3, are still in progress. See Appendix 2 for a more detailed timeline.

Key Features of the IMYMS Project

A first step in the project was to develop the *IMYMS Components of Effective Teaching and Learning* and materials to support the *IMYMS Strategy.* A number of data collection instruments were developed and used in the project – these are described here and in later sections dealing with findings of the project. A series of three two-day network meetings were also held to support the implementation of the *IMYMS Strategy* and the project in general.

The IMYMS Strategy

The *IMYMS Strategy* is a process of school and teacher improvement that was adapted from the School Innovation model developed and researched in the School Innovation in Science research project. It was modified to reflect the support structures available in IMYMS, and in particular the shift from a school based planning process to a cluster based initiative. The strategy is based on an action planning process in which schools and teachers within the cluster first audit their practice against the IMYMS Components, then develop initiatives and Action Plans arising from these. The particular features of the IMYMS Strategy are shown in Figure 1. The real focus within the model is the professional learning team, which undertakes the audit and review process and development of the Action Plan. A critical element within the SI model is leadership. In IMYMS this falls to the cluster coordinators and the IMYMS coordinators in each of the schools. The first network meeting for IMYMS incorporated a Leading Change workshop which provided information and training in the nature of the strategy, the pedagogical principles underpinning IMYMS (The IMYMS Components) and principles of leading the change process. Prior to this workshop, a briefing meeting was held for Principals which clarified expectations of schools and clusters involved in IMYMS< and the need for support. The model also incorporates principles, based on evidence from research, concerning actions within the schools and clusters that are effective in support the improvement process.

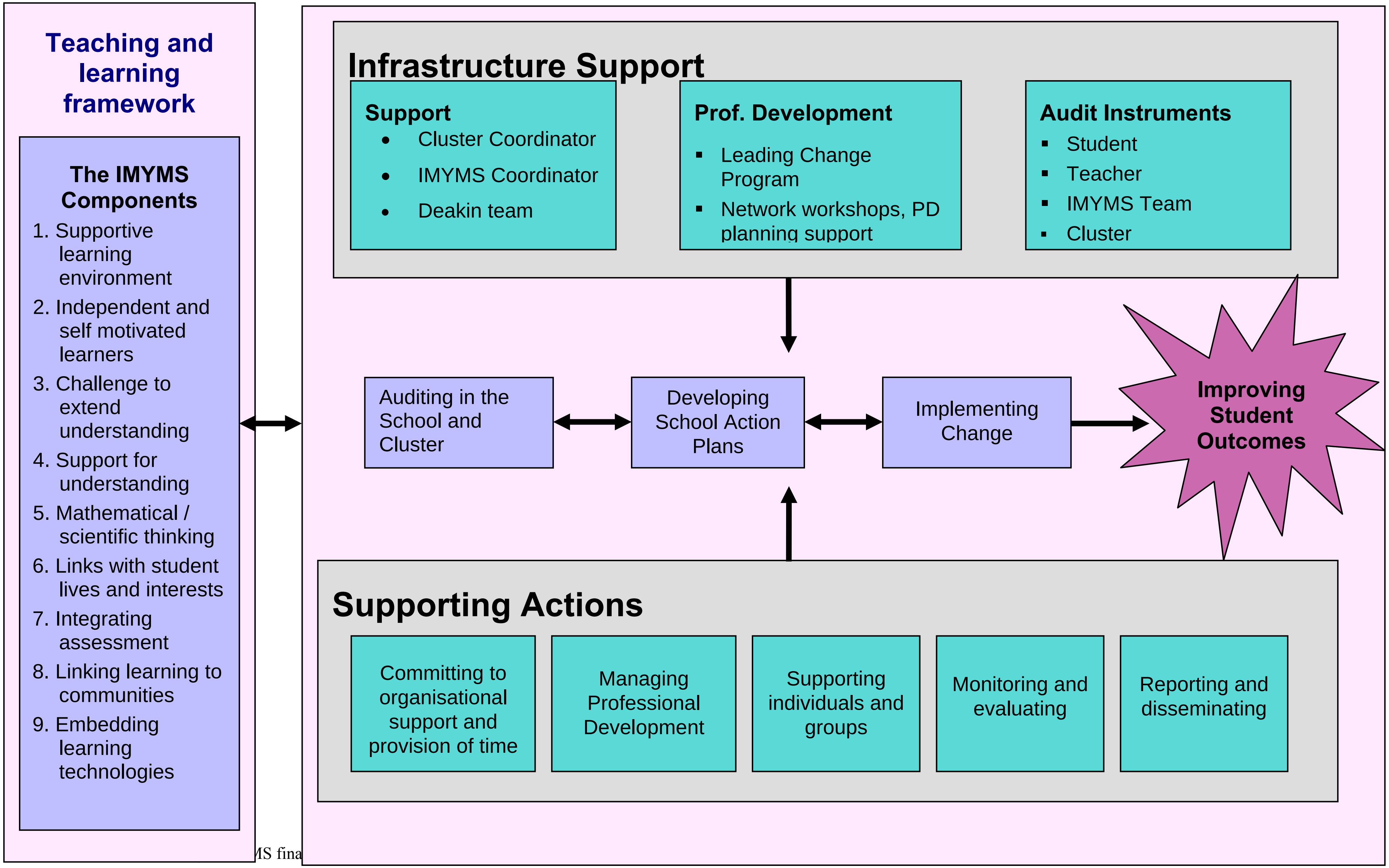
The IMYMS Components of Effective Teaching and Learning

The *IMYMS Components of Effective Teaching and Learning.* underpin the project and are the key set of referents around which schools and clusters develop their strategic plans and initiatives. They are also at the centre of the professional learning aspects of IMYMS. A number of steps were involved in the development of the Components.

- Selection of teachers of mathematics with a reputation for effective practice
- Interviews with these teachers to determine what these teachers regarded as effective teaching of mathematics, that were central to their practice
- The development of a grid on which these teachers' descriptions were aligned
- The distillation of themes from these interviews to develop a set of Mathematics Components. This was done through focus groups of mathematics education experts.
- Alignment of these themes with findings from the research literature, drawing especially on a literature review of effective teaching in middle years which had been carried out as part of the MYPRAD project (see Doig, 2004). Much of this review related to effective teaching in mathematics and science.

The components developed in this way were felt to be sufficiently similar in their intent to the Science Components, that it was decided to generate a common set of IMYMS Components of Effective Teaching and Learning to apply to both mathematics and science. Part of the rationale for doing this was to allow the project team to examine ways in which the practice and beliefs of teachers of mathematics and science are similar or different.

Figure 1: The *IMYMS Change Model* for schools and clusters



The resulting nine IMYMS Components of Effective Teaching, which are shown in Appendix 3, maintain the elements contained in the SIS components that were considered to be applicable across mathematics and science. Compared to the framework developed for MYPRAD and PoLT, the IMYMS Components have a stronger focus on conceptual aspects of learning in mathematics and science, as can be seen in the elaboration of the following three components: *Component 3 – Students are challenged to extend their understandings*; *Component 4 – Students are supported to develop meaningful understandings*; and *Component 5 –Students are encouraged to see themselves as mathematical and scientific thinkers*. This stronger focus is perhaps expected, coming from a discipline-based perspective where concerns with building knowledge and practice are more strongly felt, compared to the relatively stronger middle years focus on student well being and generic capabilities in MYPRAD. The IMYMS components have since been used to inform the School Innovation in Teaching (SIT) components, and, to a lesser extent, the Principles of Learning and Teaching (PoLT). For a detailed comparison of the SIS, MYPRAD and IMYMS components, see Tytler (2004).

The IMYMS Component Mapping Process

The IMYMS Component Mapping process was an essential part of the *IMYMS Strategy*.

Component Mapping involved teachers completing a questionnaire prior to a one-to-one meeting or interview with their IMYMS School Coordinator. In the Component Map instrument, word descriptors are used to represent five different levels of exemplification of each of the sub components. During the 45 minute interview, the Coordinator and teacher together completed the Component Map, which identifies the position that best describes the teacher's practice on each sub-Component using a scale of 1 to 5. As well as rating their practice, teachers were also asked to rate the importance they attached to each sub-Component again using a scale of 1 to 5. The role of the coordinator during the interview is to clarify the meaning of the descriptors and to probe the teacher's practice against the descriptors, to reach an agreed and validated teaching and learning profile. The exercise caused teachers to think about what they had been doing in science and/or mathematics, and what they wanted to do in the future.

The component mapping process served a number of purposes:

- to establish the Components of effective teaching and learning at the centre of IMYMS;
- to support the development of the cluster (and school) action plans; and
- as the basis for teachers to monitor their own practice.

All science and mathematics teachers teaching in the middle years at the primary and secondary schools took part in the component mapping process during the first semester of 2004. This was done separately for mathematics and science in order to build a picture of current practice in mathematics as distinct from science. The process was repeated during term 1 of 2005 for teachers new to the project, and again for all teachers in the project during term 4 of 2005.

The interviews provided an opportunity to acknowledge and affirm teachers' expertise and professionalism as well as encouraging teachers to elaborate or extend on their practice.

The IMYMS Handbook

An IMYMS Handbook was developed to support schools in the implementation of the project. The Handbook mirrored that produced for the SIS project (Deakin University, 2003b). It included: a section on effective teaching, outlining the IMYMS Components and giving detailed descriptions of how they encapsulate classroom practice; templates for the component mapping process; information for cluster and school coordinators on supporting and leading school change; information on the strategic planning strategy; instruments for auditing, including curriculum and resources audit questionnaires and a student questionnaire on perceptions of classroom practice and learning preferences; and action planning support materials.

The Handbook was distributed to school coordinators at the first "leading change" network meeting in March 2004, forming the basis of the initial training.

The Network Meetings

A series of three *Network Meetings* were held for IMYMS Cluster and School Coordinators during 2004 and 2005. Some teachers, principals and Department of Education and Training representatives were also invited to attend these meetings.

Network Meeting 1

The first of three network meetings, the *Leading Change Meeting*, was held on 3–4 March 2004. The meeting introduced the project, providing information about its background, the IMYMS School Innovation Strategy, action planning, the audit instruments (including component mapping, the student perceptions and learning preferences survey), and coordination of the project. School Coordinators were introduced to the IMYMS Components and received training on how to conduct the component mapping process. The two PhD projects associated with IMYMS were introduced, and this forum provided an opportunity to call for schools and teachers willing to participate in the video study, and to ask schools to provide copies of their Year 7 and 8 mathematics and science syllabi for the assessment study. The IMYMS Handbook was distributed to each school coordinator.

Network Meeting 2

The second of the three network meetings, held on 4–5 March 2005, focussed on school change and the assessment program. Cluster and School Coordinators received further training in facilitating school change. Two IMYMS School Coordinators shared innovations from their schools: Michelle B described the "Weed Warrior Program" at Hume Secondary College, and Wayne R described an initiative to embed problem solving within the mathematics curriculum at Parkland High School. These are included in the appendices to illustrate the different types of initiatives supported by IMYMS.

A workshop was held to inform Cluster and School Coordinators about the content and procedures for the performance testing that was to be carried out mid-year. This involved participants experiencing first hand the assessment items and equipment and the organization involved. This exercise was deemed highly successful in introducing teachers to a new and engaging way of assessing process outcomes in science and mathematics.

Data from the first year of the project, including student surveys, component mapping, and school reports, were presented and discussed. Strategies for supporting school improvement were discussed.

Network Meeting 3

The third and final *Network Meeting*, held 28–29 November2005, was designed to inform IMYMS participants of preliminary outcomes of the research to date and receive feedback from participants. Cluster and School Coordinators shared their experiences of the IMYMS project in general, discussed successes (and failures) of their action plans, and identified productive ways forward for 2006. Discussion a the meeting was recorded and forms part of the data for analysis of the change process and outcomes for the project.

Other Support Structures

Various support structures were put in place to help schools and clusters with their action planning. Cluster Coordinators from the four clusters met with the Deakin project team via telephone voice-point on a semi-regular basis. As well as providing leadership in the change process, the Cluster Coordinators played an important role in ensuring communication between schools, carried out an administrative role within the cluster, and liaised between the schools and the project team.

Members of the Deakin project team visited the clusters a number of times during 2004 and 2005 to brief the Cluster Coordinators, IMYMS School Coordinators, school leaders and teachers on project activities, including the strategic planning process, and to gather examples of innovations that schools were planning and implementing.

Data Collection Instruments

A number of instruments were developed and used in the project. The three major sets of instruments were:

- The *IMYMS Component Mapping Process* – this process, which enabled teachers to rate both their practice for each sub-Component and the importance they attached to each sub-Component on a scale of 1 to 5, was described in an earlier section and results from the process will be described in the section *Findings from the IMYMS Project*.
- The *IMYMS Student Survey* – this survey, which was administered to all students in 2004 and 2005, included a section on students' perceptions of classroom practice and attitudes towards mathematics and science, and a section on students' learning preferences. Students completed separate, parallel surveys for mathematics and science. The survey is described further in the section *Findings from the IMYMS Project*.
- The *IMYMS Student Assessment Program* – this program, which mostly consisted of cognitive and performance assessments in mathematics and science, was used with Year 6 and Year 8 students in 2005. The setting up of a range of categories within the test, and analysis to support the development of a model of student capability around which assessment could be planned, is related to research question 3 which is the province of one of the doctoral students attached to the project, Christine Kakkinen. The program of testing is described further in the section *Student Assessment Program*.

The other main data collection instruments that were used are described briefly below.

Cluster and School Coordinator Questionnaires

A questionnaire was administered to the Cluster and School Coordinators, and some teachers, at the end of 2004 and 2005 to gauge their response to the strategy and support structures offered by the project. This also probed changes in their team practices over the project. Results of the questionnaire are discussed in the section *Results and findings from the IMYMS Project*.

School Reports

Schools prepared interim reports at the end of 2004 and final reports in November 2005, detailing the initiatives the schools were targeting, progress they had made through the year, outcomes to date, and particular difficulties or challenges that the schools encountered in implementing the initiatives. Results of the questionnaire are discussed in the section *Results and findings from the IMYMS Project*.

Video Study and Associated Interviews

An extensive video study and associated interviews were carried out by one of the doctoral students, Linda Darby, to investigate the links between teachers' pedagogies in mathematics and science. This is described further in the section *Results and findings from the IMYMS Project*.

Field notes and interviews

Interviews were conducted with students of mathematics and science to probe their responses to each school subject. Interviews were also conducted with selected cluster coordinators and school coordinators. Field notes were taken of visits to clusters and schools, and at the network meetings, to form part of the data collection. Discussions at the third network meeting were recorded and analysed. Results from these data collection methods are discussed further in the section *Results and findings from the IMYMS project.*

The Student Assessment Program

The purpose of the assessment program was to collect data relating to student achievement, performance, and attitudes in mathematics and science. These data are being used to investigate the relationship between these aspects of student capability in both subject areas. They will also be used to attempt to link student learning outcomes to teachers' pedagogies, although there are confounding factors that are likely to make such an analysis somewhat problematic.

Four data collection strategies were employed:

- Attitude Surveys;
- Cognitive Assessments;
- Performance Assessments; and
- Interviews and Observations.

The Attitude Surveys were administered to all students mid- 2004 and 2005 as part of the *IMYMS Student Survey*. Cognitive Assessments were administered to all students in Years 6 and 8 in Terms 1 and 4 of 2005, while the Performance Assessment was administered once only in Term 3 of 2005 to a subset of Years 6 and 8 students. The Interviews and Observations were linked to the Performance Assessment.

The Attitude Survey will be discussed further as part of the discussion on the *IMYMS Student Survey*. The remaining three strategies are discussed below.

Cognitive Assessments

The cognitive assessment instruments focussed on subject knowledge and conceptual understandings, reasoning and thinking mathematically and scientifically, as aspects of students' mathematical and scientific capability. These instruments were in a paper-and-pencil format, with a mixture of multiple-choice and short-answer items.

The project team felt that each teacher would assess the knowledge aspect of mathematics and science learning in their classroom assessment, and this aspect of student capability was not assessed in the project. However, the other aspects were to be assessed. In order to match the assessment to students' learning experiences a questionnaire was developed and administered to all teachers involved in the project. Each teacher was asked to supply information about their intended curriculum for Years 5, 6, 7, 8, or 9 in mathematics and science for 2005 as part of the curriculum audit. This audit provided details of which *Curriculum and Standards Framework II* (CSFII) strands and outcomes that were to be the focus of teaching for each class. There was a surprising diversity of topics and outcomes addressed across the schools and it soon became apparent that it would be impossible to devise a single assessment (or even a small number of assessments) for any year level. So this information was used to construct a total of five different cognitive assessments in mathematics, and individualised cognitive assessments for each class in science. Each cognitive assessment was produced in two forms: items were rotated from the first half of a paper to the second half to provide a second form in order to ensure that a sufficient number of students attempted all items. Schools received an equal number of each form.

Items came from a variety of sources, including:

- the *Third International Mathematics and Science Study* (TIMSS) released items sets (International Association for the Evaluation of Educational Achievement, 1997a, 1997b);
- the *Science in Schools* (SIS) project;
- paraphrases of *Tapping Students' Science Beliefs* (Doig & Adams, 1993); and
- items created by the project team for understanding in mathematics and science, and for *thinking mathematically* and *thinking scientifically*..

The mathematics assessments addressed three CSFII strands (including Number and Measurement in Year 6 and Number and Algebra in Year 8) with comprehension and interpretation questions, and a separate section on *thinking mathematically*, which involved questions relating to: making connections, understanding the nature of proof, and recognition and extension of patterns.

The science assessments consisted of six questions for each of three CSFII outcomes identified by teachers as their foci, and a set of eight questions relating to *thinking scientifically*. Questions relating to particular outcomes were either comprehension or interpretation questions, at different levels of difficulty. The *thinking scientifically* questions focused on: the language of evidence and investigation, data interpretation, experimental design, the relationship between theory and evidence, and the principles of measurement.

These cognitive assessments were administered during Term 1 and again in Term 4 of 2005, to all mathematics and science students in Year 6 and Year 8. Where Year 6 or Year 8 students were in composite classes of different year levels, teachers could decide whether or not the other students attempted the test, however only Year 6 and Year 8 data is being analysed.

Performance Assessments

The inclusion of performance assessment in TIMSS was considered necessary as “this mode of assessment permits a richer and deeper understanding of some aspects of student knowledge and understanding than is possible with written tests alone” (Harmon et al., 1997, p. 5). The IMYMS project team took a similar view, and performance assessment was included in the range of assessment strategies used in IMYMS. The set of performance tasks centred on reasoning and investigative processes, and were intended to provide a different approach to assessing aspects of student capability.

All tasks were taken from the *Third International Mathematics and Science Study* (Harmon et al., 1997). The mathematics and science tasks used in this study allowed students to demonstrate their ability to make, record, and communicate observations correctly; to take measurements or record experimental data; to design and conduct a scientific investigation; or to solve problems. With one exception, the same tasks were administered to both Year 6 and Year 8 students. However the responses required were more demanding of the Year 8 students.

Schools were supplied with the equipment required for the tasks, and members of the IMYMS team and recruited Deakin University education students assisted teachers in administering the assessment tasks to Year 6 and Year 8 students in Term 3 of 2005.

Interviews and Observations

A sample of teachers and students were interviewed after the completion of the performance assessment procedure. Student interviews sought to gather insights from the students about the performance assessment process, their attitude towards this mode of assessment, and how they solved particular tasks. Teachers interviewed were asked to assess the value of this mode of assessment, their view of the process, and the impact on their professional perspectives on assessment techniques.

Feedback to teachers

The curriculum and strategic practices audit instruments were designed to be used by schools and clusters in the strategic planning process. Results of student surveys which included the student perceptions and learning preferences data, were electronically processed and collated and returned to teachers in a short time frame, to assist them in their planning. The test assessments were individually tailored to schools’ curricula. Individual student results and class summary information from the pre-test was prepared and confidentially provided to each teacher within a tight time frame so that they could use the information to plan their learning units. These pre-tests thus acted as formative assessment. The same tests were administered at the end of the year as summative assessment. Summaries of results for Clusters were also provided to Cluster Coordinators. Thus, this battery of instruments and the processes used was intended to provide timely and comprehensive feedback to schools and teachers to assist them in their planning processes at the cluster, school and classroom level.

Analyses based on the various IMYMS data collection instruments

A variety of analyses have been carried out using these data source gathered during the IMYMS project. Most of these have been completed and a number have now been published, or presented at international conferences. Some are in the process of being submitted for publication, while others are still incomplete and will be the subject of publication over the next six months.

Analysis of test results

One of the doctoral students, Christine Kakkinen, will analyse the data from the cognitive and performance assessments and the student surveys to investigate the relationship between these aspects of student capability within and across the two subject areas. This aspect of the project is running behind schedule, due to problems created by the late start of the project, and serious illness and resulting surgery for Christine, which has meant a three-month break in her doctoral program and a request for a six-month extension of her scholarship.

The data will also be analysed in terms of student gains in the cognitive assessments, levels of performance in the performance assessments, attitudes to mathematic and science, and possible links between these and teachers' pedagogies, although, as stated earlier there are many confounding factors that are likely to make such an analysis problematic.

Analyses based on the tests, surveys and other instruments

The following analyses are described in this report. Some are incomplete or proved inconclusive.

Table 1: Analyses undertaken in IMYMS, and data sources used

Analysis	Data sources
Comparison of pedagogical practices of science compared to mathematics teachers	Component map
Change in teacher component map scores over the project	Component map
Linking student learning outcomes to the component mapping scores of the teacher	Component map Student achievement tests
Analysis of student perceptions as a window into current practice in mathematics and science	Student perceptions
Comparison of student perceptions profiles for mathematics vs. science, primary vs. secondary.	Student perception instrument
Comparison of student learning preferences for science vs. mathematics	Student learning preferences
Investigation of the nature of initiatives and progress made by schools	IMYMS school reports
Changes to mathematics and science team practices	Coordinator questionnaires
Student achievement in learning for each cluster in 2005.	Pre and post test scores
Change in student perceptions over the project	Student perceptions surveys
Linking teacher component mapping scores with student achievement and perceptions	Component map Student perceptions survey
Exploration of pedagogies and beliefs of teachers of mathematics and science	Video data, interviews and focus groups
Establishment of Components of effective teaching and learning in mathematics and science	Interviews with effective teachers
Construction of a model of student capability in mathematics and science, and reliable ways of assessing students	Achievement & performance tests, student survey

Results and findings from the IMYMS Project

In this section we will describe in more detail the research methods and data collection, and also the major findings that came out of these. The research methodology is mixed mode, consisting of qualitative analyses of interviews and field notes and school reports, and quantitative analyses of surveys, component mapping data, and test results. The reporting will follow these different data collection instruments.

The IMYMS Components: Mathematics and science pedagogy

The development of the IMYMS Components built on and mirrored the methods used to develop the SIS Components. The Components were developed in the latter part of 2003 prior to the project starting in the chosen clusters. Mathematics educators and Education Department mathematics personnel were consulted to generate a list of teachers known to be good mathematics teachers. The selection thus represented teachers who were recognised by peers as effective and articulate in their mathematics teaching. From this list 17 teachers were chosen (partly from convenience, and partly because many had been recommended by more than one educator) to be interviewed. Eight were primary and nine were secondary teachers. The team generated a list of questions to cover their history of teaching, their teaching context, learning environment, strategies for supporting learning, purposes, commitments and interest, and curriculum organization.

All the interviewees showed a strong commitment to: the need to cater for individual differences; the development of student autonomy and interest by framing activities in real life contexts; making connections; and planning for multiple entry points to tasks. Many teachers, particularly primary teachers, talked of multiple intelligences and the need to approach tasks in a variety of ways. All focused on the need to keep track of and support individuals, although they had different ways of doing this, either by moving around the room while students were working, or by allowing for flexibility in tasks. A number of these teachers had specialised in or set up schemes in their schools to diagnose student learning difficulties and to support students at risk, driven by a knowledge that early failure in mathematics closed off future opportunities. There was a sense in the interviews of the teachers battling common perceptions of mathematics, and, in some cases, explicit critique of curriculum demands and traditional ways of teaching mathematics.

There was a strong sense in these interviews of a tension between problem solving and open-ended tasks, which focus on process and do not presume a single correct answer, and the need to build a sequential core of knowledge and skills to move students to the next level. More so than with science, there was a feeling of the explicitness of “what is to be known”, together with a commitment to analytic thinking and problem solving processes. There was also a strong sense of responsibility to help students achieve sufficient understanding to deal with the next level of schooling, and a sense of being part of what is recognised by the school community as a core intellectual pursuit.

In a preliminary analysis of the data from these interviews, the following themes emerged: the social-emotional dimension of value and respect and support; supporting a community of inquiry; catering for diversity; supporting student independence and responsibility**;** encouraging deeper levels of thinking; connecting to students’ lives; scaffolding for understanding; assessment and monitoring; and linking with community.

A literature review of effective teaching in middle years had been carried out as part of the MYPRAD project (see Doig, 2004). Much of this related to effective teaching in mathematics and science. In focus group discussions involving the IMYMS team and others mathematics educators, the themes from the interviews, and those represented strongly in the mathematics education literature, were pulled together to develop a draft set of Mathematics Components.

There was sufficient similarity between these Mathematics Components and the SIS Components to make it productive to produce a combined set of IMYMS Components that capture the essence of practice in both subjects. The IMYMS Components also benefited from the prior development by members of the team of the MYPRAD Components which were strongly influenced by literature on Middle Years Pedagogy. Thus, the IMYMS Components:

- Represent a further development of the SIS Components in that they more strongly represent Middle Years themes of classroom relationships, involving pro-social aspects of support and encouragement (Component 1);
- Include themes that are present in science pedagogical thinking but are more strongly present in mathematics. These mainly relate to the inclusion of elements of learning that emphasise conceptual abstraction, and the need to master difficult conceptual material. Specifically, these are represented by the sub-components
  - Subject matter is conceptually complex and intriguing, but accessible
  - The teacher clearly signals high expectations for each student
  - Learning sequences involve an interweaving of the concrete and the abstract/conceptual
- Retain, from the SIS Components, pedagogical elements that highlighted aspects of teaching that are generally not considered central to mathematics, specifically:
  - The strong emphasis on students' lives and interests is seen differently in mathematics
  - The connection with communities and practice beyond the classroom
  - The engagement with a rich and contemporary view of the subject does not echo strongly with mathematics classroom practice in the same way as with science.

On the other hand, most of the sub components sit very well with findings from the science and the mathematics effective teacher interviews. In some cases the bringing together of the themes highlighted the differences in language used in the two areas, or the way the same language points to different practices (the contrast of concrete and abstract, for instance, has different shades of meaning and represents different practices in the two subjects, for instance, and the meaning of 'problem solving' and 'investigation' and 'evidence' are also different in interesting ways). Tytler (2004) provides a detailed comparison of the SIS, MYPRAD and IMYMS components.

The decision to combine the insights from the previous interviews with science teachers, from SIS, and the insights from these mathematics teacher interviews, into one set of common components, can be seen as a working hypothesis that teaching in the two areas is different in some respects and similar in others. The generation of one set of components allows us to compare the importance of particular pedagogical practices in mathematics, compared to science. The conversation that surrounded the generation of the common set also provided the team with the opportunity to generate common understanding and language, and threw into relief some significant differences in practices and presumptions in the two discipline areas. These insights will be part of the research outcomes of the project that will be reported on.

The IMYMS Component mapping findings

As stated earlier, all participating teachers took part in the component mapping process at the beginning of their involvement in the project and at the end of 2005. Teachers of mathematics and science completed one survey for each of the subjects they taught. Each survey had two parts – one relating to their practice in terms of each of the sub-components and the other to the importance they attached to each sub-component.

In this section we will compare 2005 data relating to teaching practice for mathematics and science and for primary and secondary teachers. This will draw on analyses that have been reported in publications, some of which are attached to this report. The number of teachers component mapped in 2005 is given in Table 2

Table 2: Number of teachers component mapped at the end of 2005

2005	Maths	Science	Maths & Science
Primary	2	0	44
Secondary	27	15	18

Differences in Teachers' Practice between Mathematics and Science

Appendix 11 shows the data for teachers' rating of their practice in mathematics and science at the end of 2005 and the differences between these for secondary and primary teachers for practice.

Secondary teachers

The first table compares the practice of secondary science and mathematics teachers. This is the comparison that will bring out differences in the culture of mathematics and of science, since one might expect secondary teachers to much more strongly represent disciplinary interests and practices than primary teachers who teach across all subjects.

First, in looking at the percentage of teachers scoring 4 or 5 on the sub-components, the practices both mathematics and science teachers are least likely to represent highly are, in order for mathematics teachers:

8.1 The learning program provides opportunities to connect with local and broader communities (5.4/10.3%)

The components that mathematics teachers least represent, yet are represented at a comparatively high level by science teachers, are:

8.2 Learners engage with a rich, contemporary view of mathematics and science knowledge and practice (10.8/48.3%)

1.2 The learning environment is characterised by a sense of common purpose and collaborative inquiry (27.0/65.5%)

9 Learning technologies are used to enhance student learning (35.1/48.3%)

For both mathematics and science it is clear that links with community practices is a little represented practice, and this was a focus for a number of schools within IMYMS. The different rating for 8.2 may reflect the stronger attention given to the nature of science (NOS) in science teaching compared to the nature of mathematics which is rarely represented in mathematics curricula. With 1.2 it could be that discussion of experimental work or other ideas in science is what is creating this difference. The other sub-components with significant differences in favour of science are

- *4.5 interweaving concrete and abstract* which is surprising since this was thought to be a mathematics practice but it could be that science teachers think of activity based work when responding to this
- *5.1 Investigating and problem solving* which science teachers may see aligned to student managed practical work
- *5.2 Engage in reasoning and argumentation,* and
- *1.3 providing a safe place for students to take risks*

These differences can be seen as consistent with practices in mathematics that are focused on the teaching of a sequential body of skills and processes and conceptual material, as against the focus on practical work and objects and real world implications. Mathematics teachers rating themselves higher on only one sub-component, namely:

7.1 Learners receive feedback to support further learning.

Which again would seem related to the need, in mathematics, to build on conceptual ideas and ensure that learners master particular skills and practices before moving to the next level. Thus, we can see that the component mapping process is highlighting significant differences in the culture of science and mathematics teachers.

Primary teachers

In contrast to the case for secondary teachers, there were only two sub-components where there was a significant difference even at the 0.05 level for primary teachers. Both of these had teachers rating themselves higher for mathematics than for science. These sub-components were:

1.1 The teacher builds positive relationships through knowing and valuing each student; and

4.1 Teaching strategies explore and build on students' current understandings.

In both cases one might expect the higher rating to relate to the much stronger representation of mathematics in the primary curriculum, compared to science, The greater representation of both 1.1 and 4.1 in mathematics may relate to the fact that mathematics is seen as a central, and a sequential subject in primary schools, more so than science, and thus attention to and support of individual students to master each stage in preparation for the next, could be expected to be deemed a central aspect of the teachers' responsibility.

Correlating mathematics and science

A question that arises in comparing subject cultures and pedagogies in mathematics and science is: does the same teacher have similar teaching and learning practices in mathematics and science? There were 69 primary and 28 secondary teachers involved in IMYMS who taught, and were component mapped in, both mathematics and science. By comparing the component mapping results for these teachers in the two subjects it is possible to examine their practice across these. The question can be asked at a very detailed level by analysing patterns for individual sub-components, and this analysis will be undertaken in due course. Table 3 shows the correlation between teachers' mean component map score in mathematics and science. Where these teachers were component mapped twice in either mathematics or science, the mean score represents the mean of both these scores.

Table 3: Correlation coefficient and means, for teachers teaching across mathematics and science

	N	Maths mean	Sci mean	Maths/Sci correl
Secondary	28	3.41	3.62	0.72
Primary	69	3.65	3.49	0.76

It might be expected that primary teachers in particular would have similar patterns of practice in both mathematics and science, but that this would be less true of secondary teachers since the subject cultures are more distinct here and classes run differently. However, Table 3 shows that in both cases the correlation coefficient is high, meaning that individual teachers' pedagogies in science and mathematics have similar characteristics. Table 3 shows an interesting and unexplained reversal in mean scores for science and mathematics, at primary and secondary level. Primary teachers rate themselves higher in science, whereas secondary teachers rate themselves higher in mathematics.

Differences between Primary and Secondary Teachers' Practice

Appendix 12 shows the same data for teachers' rating of their practice in mathematics and science at the end of 2005, together with the differences between secondary and primary teachers' ratings for practice in mathematics and science.

As can be seen from the first table, in mathematics primary teachers rated themselves significantly higher at a level of 0.01 in one third of the sub-components, with no sub-component having a significantly higher proportion of secondary teachers rating themselves highly. The differences for science were much less pronounced, with primary teachers rating themselves significantly higher at a level of 0.01 on only three sub-components and secondary teachers on one sub-component.

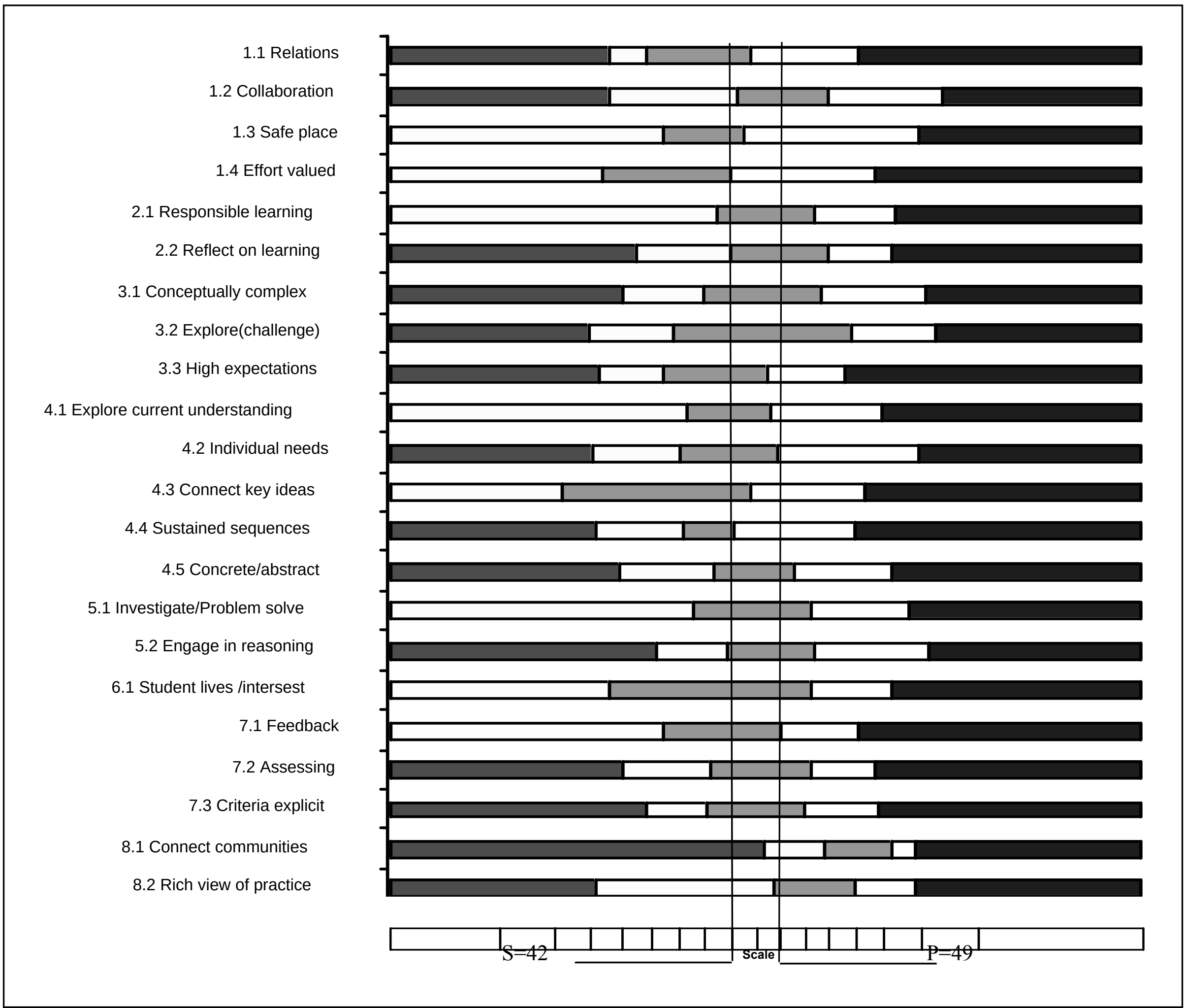
It would thus seem that there is a significant change in culture in mathematics teaching across the primary-secondary transition, with primary teachers much more strongly representing the pro-social pedagogies (collaboration, providing the opportunity for risk taking, and attending to individual needs), aspects of mathematics related to exploration and problem solving, a wider set of assessment strategies, and a richer view of mathematics practice. From the standpoint of this survey, secondary mathematics teaching practices seem quite limited compared to both primary teachers' practice, and science teaching and learning.

These findings are discussed in Doig, Groves, Tytler and Gough (2005), but in that case with the analysis making use of Item Response Theory (IRT) to develop a variable map with an interval scale to better show the distances between responses on each of the sub-components. This paper is appended as Attachment 1.

During the project the team has been exploring the use of Rasch modelling to generate displays that allow better and more powerful interpretations of the teacher and student data. Figure 2 shows an ordinal map of the same data for mathematics that was used to generate the tables in Appendix 12, but this time with the relative difficult of teachers scoring at the different levels on each of the sub-components. The right hand side of the dark bars on the left represent threshold scores of 1, while the dark bars on the right represent the threshold scores between 4 and 5, for each component. Thus, a secondary teacher scoring on the mean line (S=42) is most likely to score 3 on sub-component 1.1, not having reached the threshold for a score of 4. A mean-scoring primary teacher, on the other hand, is most likely to score 4 on the same sub-component. The shaded lines can be read as the relative difficulties of each score on each sub-component, so that the most difficult sub-component to reach the threshold for scoring 2 is 8.1, connecting with communities. A mean-scoring secondary teacher will most likely score 1 on this sub-component but will score 2 or 3 or even almost 4 (for 4.4 sustained sequences or for 1.4 valuing effort) on other sub-components.

Such a map can indicate the relative difficulty for teachers to move between scores on the sub-components, with the distance between the threshold for a score of 2 and a score of 3 being less for sub-component 1 than it is for sub-component 2, for instance, represented by the shorter white bar.

Figure 2: Ordinal map of mathematics practice from the Component Mapping, with primary and secondary means

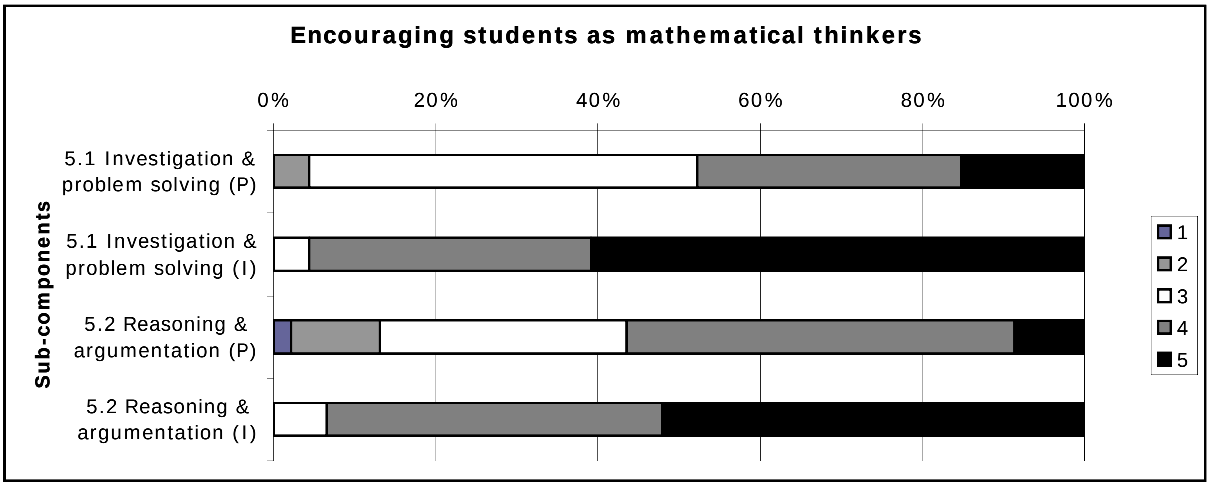


Such a mapping process is being used to assign scores for each teacher on the component map overall, to explore links between teacher practice and student outcomes, and also explore teacher change. A further refinement of this map has been developed which highlights differences at each step between the two populations. This will be described in the section below, on student survey results.

Comparing importance and practice for primary teachers of mathematics

In the component mapping process teachers discussed with coordinators their score on each sub-component and also ranked the importance they gave to that sub-component on a score of 5. Figure 3 compares primary teachers' practice and beliefs about the importance on the two sub-components related to students seeing themselves as mathematical thinkers. This figure, and the discussion below, is represented in Groves and Doig (2005)

Figure 3: Comparison of teachers' practice (P) and beliefs about importance (I) for the sub-components of IMYMS Component 5



This figure shows clearly that a much greater proportion of teachers rated each of the sub-components as 'highly important' (a score of 5) than those ranking their practice at level 5. This was repeated across all sub-components. Similarly, very few teachers rated any sub-component as scoring 1 or 2 in importance, but their own practice was sometimes rated at 1 or 2.

The IRT analysis described above has also been used to place the practice and the importance ratings on the same ordinal scale, to allow a meaningful comparison (see Groves & Doig, 2005), and this approach will be used for further analysis. For this analysis, for almost every sub-component and every level of response, teachers' views of the importance exceeded their scores for their own practice. An extreme example of this occurs for SC4.2 "Individual students' learning needs are monitored and addressed", where teachers rated this as extremely important but their practice fell far short of this ideal. This is an interesting result in itself, showing that teachers attach a high importance to this aspect of their teaching but are not able to rate their practice equally highly. Moreover, teachers' views can be seen as validating the importance of the sub-components for effective teaching and learning, with views of importance being negative only extremely rarely.

Among the sub-components themselves, apart from SC4.2, the sub-components placed highest on the scale for scoring 5 on teacher practice (and therefore hardest to achieve) were 1.2, 5.2, 3.2, 3.1 and 4.5. This is of some concern as these sub-components deal with challenging students' conceptual understandings and expecting them to engage in higher-order mathematical thinking. SC8.1, concerning connecting with communities, and SC8.2, concerning rich views of practice, had a high threshold for scoring 5 on both importance and practice, indicating that relatively few teachers believed these to be highly important aspects of their teaching. This suggests that these aspects are more closely linked to teachers' beliefs and practice in science than mathematics.

Change in Component mapping scores over the project

An important intended outcome of IMYMS was an improvement in classroom practice in the direction indicated by the IMYMS Components. This should be reflected in an increase in scores over the period of IMYMS. For this purpose, mean component mapping scores were compared for teachers who had been component mapped on two occasions, to ascertain the extent of change. This was done for both mathematics and science. Tables 4 and 5 give the changes in component mapping scores and changes for primary and secondary teachers of mathematics and science, over the duration of their involvement in the project. The data is broken down by cluster.

Table 4: Changes in mean component mapping scores for mathematics

	N	Math 04	Math 05	Change
Cluster A Primary Average	17	3.51	3.74	0.23
Cluster B PrimaryAverage	2	3.22	3.46	0.24
Cluster C Primary Average	16	3.60	3.78	0.18
Cluster D Primary Average	4	2.65	4.20	1.55
Primary average	*39*	*3.44*	*3.79*	*0.35*
Cluster A Secondary Average	10	3.42	3.63	0.22
Cluster B Secondary Average	1	3.52	2.48	-1.04
Cluster C Secondary Average	11	3.47	3.27	-0.20
Cluster D Secondary Average	7	3.53	4.11	0.58
Secondary average	*29*	*3.47*	*3.57*	*0.10*
Grand average	*68*	*3.45*	*3.7*	*0.25*

The clusters are: A Parkland, B Ocean, C Surfcoast, D Hume

Table 5: Changes in mean component mapping scores for science

	N	Sci 04	Sci 05	Change
Cluster A Primary Average	16	3.48	3.98	0.50
Cluster B PrimaryAverage	2	3.04	3.57	0.52
Cluster C Primary Average	16	3.13	3.41	0.28
Cluster D Primary Average	4	2.72	4.08	1.36
Primary average	*38*	*3.23*	*3.73*	*0.50*
Cluster A Secondary Average	4	3.49	4.13	0.64
Cluster B Secondary Average	1	2.96	4.09	1.13
Cluster C Secondary Average	4	3.38	3.32	-0.07
Cluster D Secondary Average	7	3.77	4.37	0.60
Secondary average	*16*	*3.56*	*4.02*	*0.46*
Grand average	*54*	*3.32*	*3.81*	*0.49*

The clusters are: A Parkland, B Ocean, C Surfcoast, D Hume

From Tables 4 and 5, there is overall increase in the component mapping means, but the changes are greater for science than mathematics. The most substantial changes for mathematics occur in cluster D, but with small numbers. The overall growth is greater for primary than secondary teachers. The increase in component mapping scores should be seen against a backdrop of a finding in the SIS project that scores for many teachers drop from the first to the second mapping, because teachers begin to judge themselves more critically on becoming more familiar with the deeper meaning of the components. The drop in score for the secondary school in Cluster C could be partly because of this, and also partly because there was some indication (see discussion in the change section below) of problems with the integrity of the mapping process particularly on the second occasion.

The numbers of teachers component mapped twice during IMYMS is small partly because of the changes in teachers involved in the project over the two years. Part of the difficulty in ensuring validity of the process is the change in coordinators in clusters B and D, between the first and second mappings. A further complexity in this analysis comes from the fact that some of these teachers had joined the project at the beginning of 2005 and their first mapping occasion was a full year later than for those teachers who were traced over two years. To ascertain whether this made a difference, changes were calculated for one year compared to two year teachers, for primary teachers. There were too few secondary teachers joining in 2005 to make the comparison meaningful. Table 6 shows this analysis.

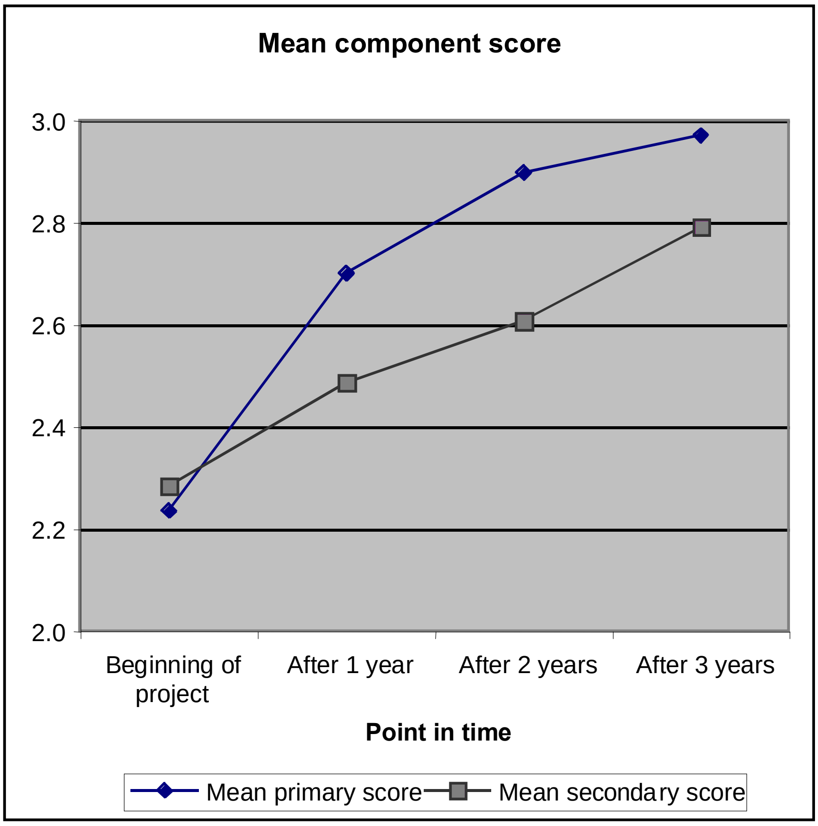
Table 6: Comparison of changes in mean component mapping after one and two years in the project.

	N	Beginning mean	End mean	Change
One year primary mathematics	11	3.47	3.8	0.33
Two year primary mathematics	40	3.43	3.78	0.35
One year primary science	12	3.33	3.7	0.37
Two year primary science	26	3.19	3.75	0.56

For science, there is a difference, with the two year participants achieving a greater change in their score. The change for mathematics is no different for both groups.

These changes of component mapping means can be compared to the changes experienced in the SIS research project, shown in Figure 4. The changes for primary teachers are approximately 70% of the SIS change over one year for primary teachers and approximately 50% for mathematics and 80% for science. The comparison is complicated by the fact that the SIS component mapping was on a four point scale. For secondary teachers, the change represents approximately 30% and 150% for mathematics and science respectively. These comparisons are very uncertain, given the low numbers and factors threatening validity described above, but nevertheless provide encouragement that IMYMS has achieved a respectable change in teacher practice over the life of the project.

Figure 4: Growth curve constructed from mean Component Mapping scores for all components, for the SIS project (Tytler, in press)



The IMYMS Student Survey

The IMYMS Student Survey was comprised of two scales: the first dealing with student perceptions of their mathematics and science classrooms and their dispositions towards mathematics and science (36 items), and the second dealing with students' learning preferences in mathematics and science (24 items). Each scale was a Likert scale, with four response categories for the perceptions scale (Strongly Disagree, Disagree, Agree and Strongly Agree), and three response categories for the preferences scale (Not Helpful, Somewhat Helpful, and Very helpful). All students completed two surveys (one for mathematics and once for science) in mid-2004 and 2005.

Student perceptions scale statements were linked to the nine IMYMS Components with three survey statements matched to an IMYMS Component, giving twenty-seven statements in all. Additionally, there were a total of nine statements on student attitudes towards mathematics and science, focussing on enjoyment, aspirations to achieve, and future usefulness. For a list of student perceptions mathematics items grouped by component see Appendix 4. The items related to enjoyment, aspirations to achieve, and future usefulness appear under headings 10, 11 and 12. A similar set of items was provided for the student survey in science.

For the student learning preferences scale, students were provided with a list of 24 activities that could be done in mathematics or science classes and asked to rate their helpfulness (see above). Appendix 5 shows the list of student mathematics learning preferences items. The same items were used for student learning references on the science survey. The results provided information on the types of mathematics and science activities that were valued by students, which could then be matched against current practice.

Appendix 6 shows the proportions of responses in each of the four categories for the student perceptions data across all clusters for secondary and primary mathematics and science in 2004 and 2005. An analysis of this data shows that there was no significant change in student perceptions and attitudes between 2004 and 2005. Given this, the discussion below will be based on the 2005 data.

A Summary of Student Perceptions findings

The student perceptions data will be analysed for the insights it can offer concerning practice in mathematics and science classes, and the differences between these. Graphs giving the results across all four clusters can be found in Appendix 6.

Primary mathematics and science

Overall primary students' perceptions of teaching practices in both mathematics and science were very positive, with only four items in mathematics and three in science having fewer than 60% of students showing agreement or strong agreement. These patterns, however, provide insights into the different practices prevailing in mathematics and science in primary school classrooms.

For mathematics, these low scoring questions were:

8 In my maths class we work on projects outside school or have people come to talk to us;

18 The maths we do is often connected to things I am interested in outside school;

19 My teacher always tells us how our maths will be marked; and

32 In my maths class we look at things in the news or work on problems that affect our lives.

In science they were:

19 My teacher always tells us how our science will be marked;

18 The science we do is often connected to things I am interested in outside school; and

32 In my science class we look at things in the news or work on problems that affect our lives.

For both mathematics and science, therefore, the subjects are not highly regarded by students as either connected to their lives and interests outside school or problems that affect their lives. In mathematics, this is perhaps understandable but not laudable. For science however, which is a subject that should connect to students' interests and seen to be relevant to their lives, this pattern of response is disturbing. It is, however, consistent with a large body of research on student responses to school science.

Secondary mathematics and science

Overall secondary students' perceptions of both mathematics and science, while still very positive, were less positive than those of the primary students. In this case, there were six mathematics items and four in science having fewer than half of the students showing agreement or strong agreement. For mathematics, these statements were:

8 *In my maths class we work on projects outside school or have people come to talk to us;*

18 *The maths we do is often connected to things I am interested in outside school;*

32 *In my maths class we look at things in the news or work on problems that affect our lives;*

9 *We use technology to explore new maths ideas;*

6 *In maths we study things that interest me; and*

21 *We use technology to solve maths problems.*

In science they were:

20 *We learn about ways that science is used in everyday life;*

18 *The science we do is often connected to things I am interested in outside school;*

32 *In my science class we look at things in the news or work on problems that affect our lives; and*

36 *What I learn in science helps me in everyday life.*

Again, as with the primary students the pattern is clear. Students do not see their mathematics or their science connecting to their interests or their daily lives. In mathematics there is a further view that technology is not commonly used. The low score for item 36 for science is not mirrored in mathematics, reflecting the general result that mathematics is seen to be useful, more so than science.

High scoring statements for mathematics and science

The statements gaining high levels of agreement for mathematics, for both primary and secondary students, were those relating to students aspiring to do well in mathematics (see Appendix 4), those concerning the usefulness of mathematics, and also:

15 *My teacher expects everyone to do their best in maths*

Primary but not secondary mathematics students, and also primary science students, scored as high the statement:

30 *My teacher tries to make maths interesting for everyone*

The patterns of high scoring statements were not generally as strong for science. Nevertheless, the 60% SA or A responses for the statements concerning science being fun and enjoyable tends to contradict research giving strong messages about students' negative attitudes to school science. The findings are however consistent with some reports (see Tytler et al. 2008). Nevertheless, this 60% level of agreement is considerably lower than the 80% agreement rate of primary students.

Differences in Perceptions between Mathematics and Science

Appendix 7 shows the differences between student perceptions in mathematics and science, based on the 2005 data. Items have been ordered based on the difference in percentages between mathematics and science students rating each item as Strongly Agree.

The second column of figures, SA + A, represents the difference in percentages between mathematics and science students rating each item as Strongly Agree or Agree. Data for each item based on Agreement (i.e. rating an item with Agree or Strongly Agree) in the mathematics and science surveys were compared using a χ^2 test with 1 degree of freedom. The figures in the SA + A column are annotated to indicate significance of any differences.

As can be seen from the two tables, there are substantial differences in the way both primary and secondary students perceive the two subjects. Students in both primary and secondary schools perceive mathematics to be much more useful to future success and really want to do well in mathematics, while science is seen as more fun and more interesting, with students believing they work much more on projects outside school or have people come in to talk to them. They feel it is more ok to say what they think in science classes. Students also see more of a focus on investigations and problem solving in mathematics than in science and believe they are encouraged to work things out for themselves.

Differences in Perceptions between Primary and Secondary Students

Appendix 8 shows the differences between primary and secondary student perceptions in mathematics and science, based on the 2005 data. The two tables have been derived in the same way as those in Appendix 7.

Almost every item on both tables shows a significant difference at a 0.001 level between primary and secondary student perceptions, with all but one significant difference showing primary students to have responded more positively. The one exception, which occurs on both the mathematics and science tables, was:

19 *My teacher always tells us how our maths (or science) will be marked,*

where secondary students are much more likely to agree or strongly agree with the statement, reflecting the stronger focus on test regimes in secondary school.

It is interesting to note the items where there is no significant difference between primary and secondary student responses. In mathematics these were:

23 *I really want to do well in maths; and*

17 *In my maths class we do lots of investigations and problem solving.*

In science these were:

33 *In science we can use technology to help with our work;*

20 *We learn about ways that science is used in everyday life;*

9 *We use technology to explore new science ideas; and*

21 *We use technology to solve science problems.*

Analysing and reporting ordinal data

As described in the Component Mapping section above, we have been exploring ways of analysing and reporting data from these ordinal scales in a way that will allow a clearer view of differences between data sets and more defensible conclusions to be drawn about the relative perceptions of mathematics vs. science or primary vs. secondary students, or teachers of mathematics vs science, for instance. This involves the use of Item Response Theory (IRT) where a common scale is constructed using Rasch modelling wherein the intervals have meaning. Doig and Groves (in press: Attachment 3) describe this process and the relative merit of different sorts of analysis and display generated within the IMYMS project. An ordinal map is shown in Figures 5 and 6 which displays a comparison between the mean scores for primary compared to secondary students, and the pattern of responses one might expect for a high or a medium scoring student. A comparison of the thresholds for the Strongly Agree category shows, as an example, the relative likelihood of strongly agreeing with the statement *My teacher tries to make maths interesting for everyone* compared with the lower likelihood of strongly agreeing with the statement *The maths we do is often connected to things I am interested in outside school*, within the same Component.

Figure 5: The IMYMS student perceptions reported on an Ordinal Map – part A

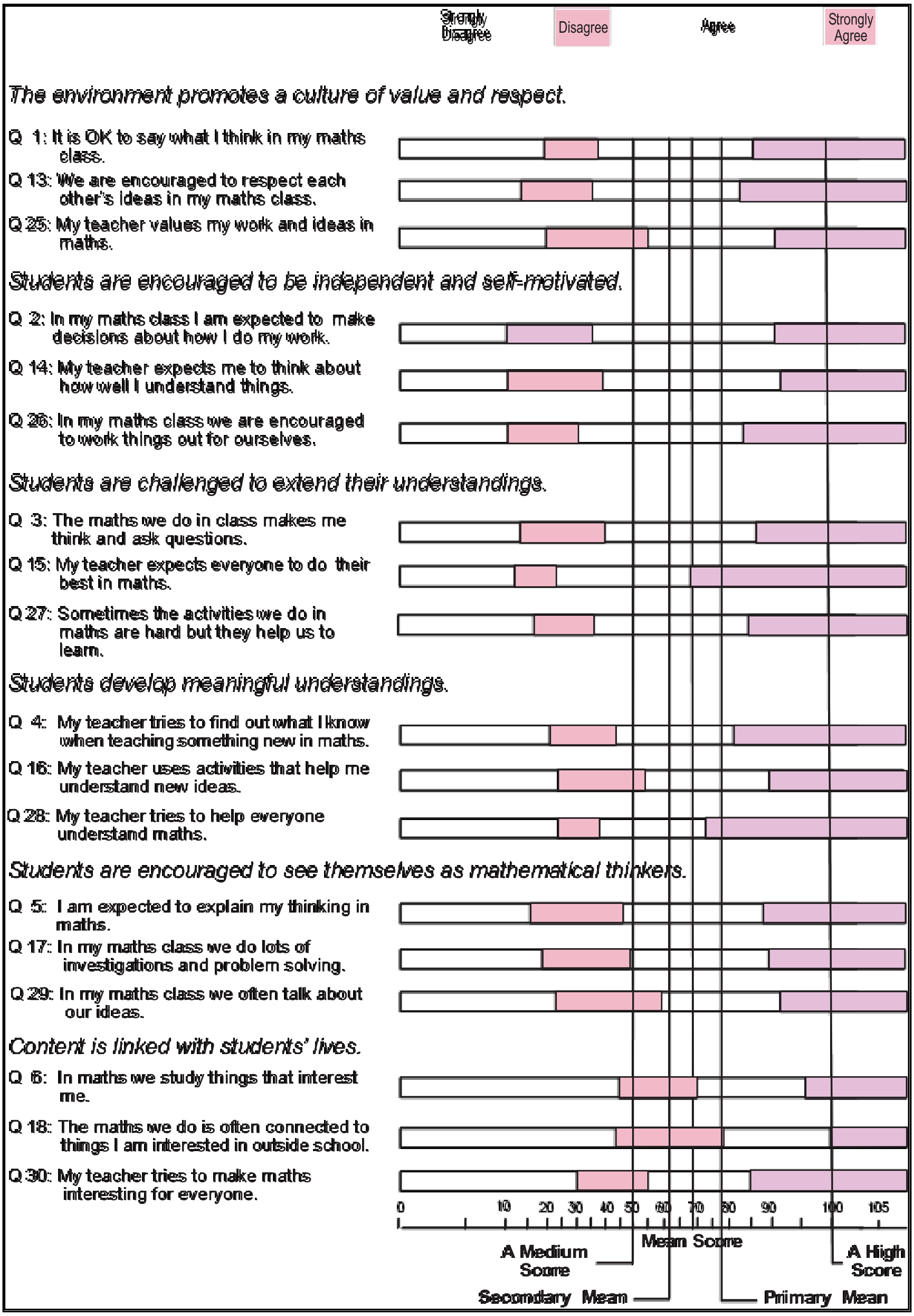
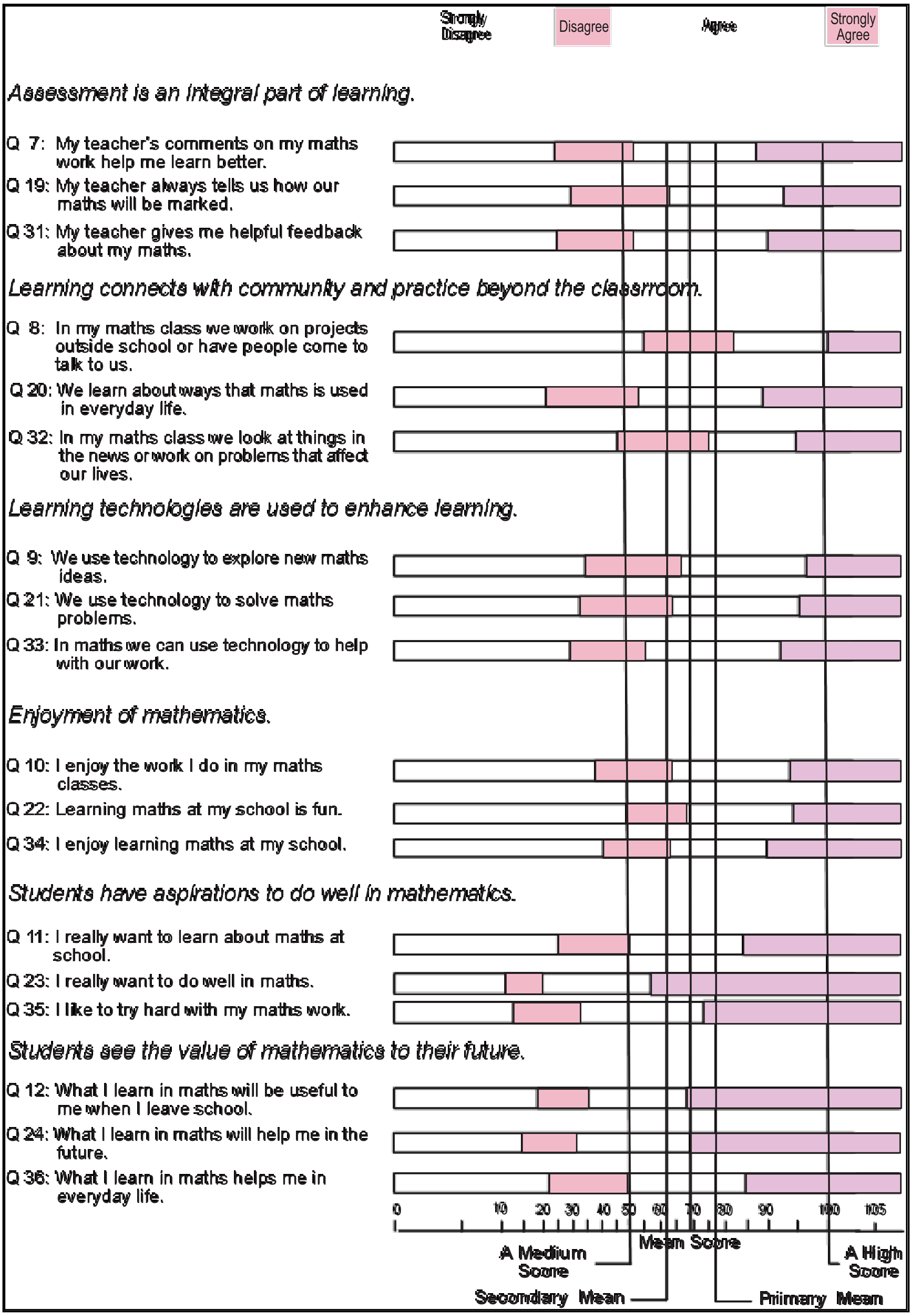
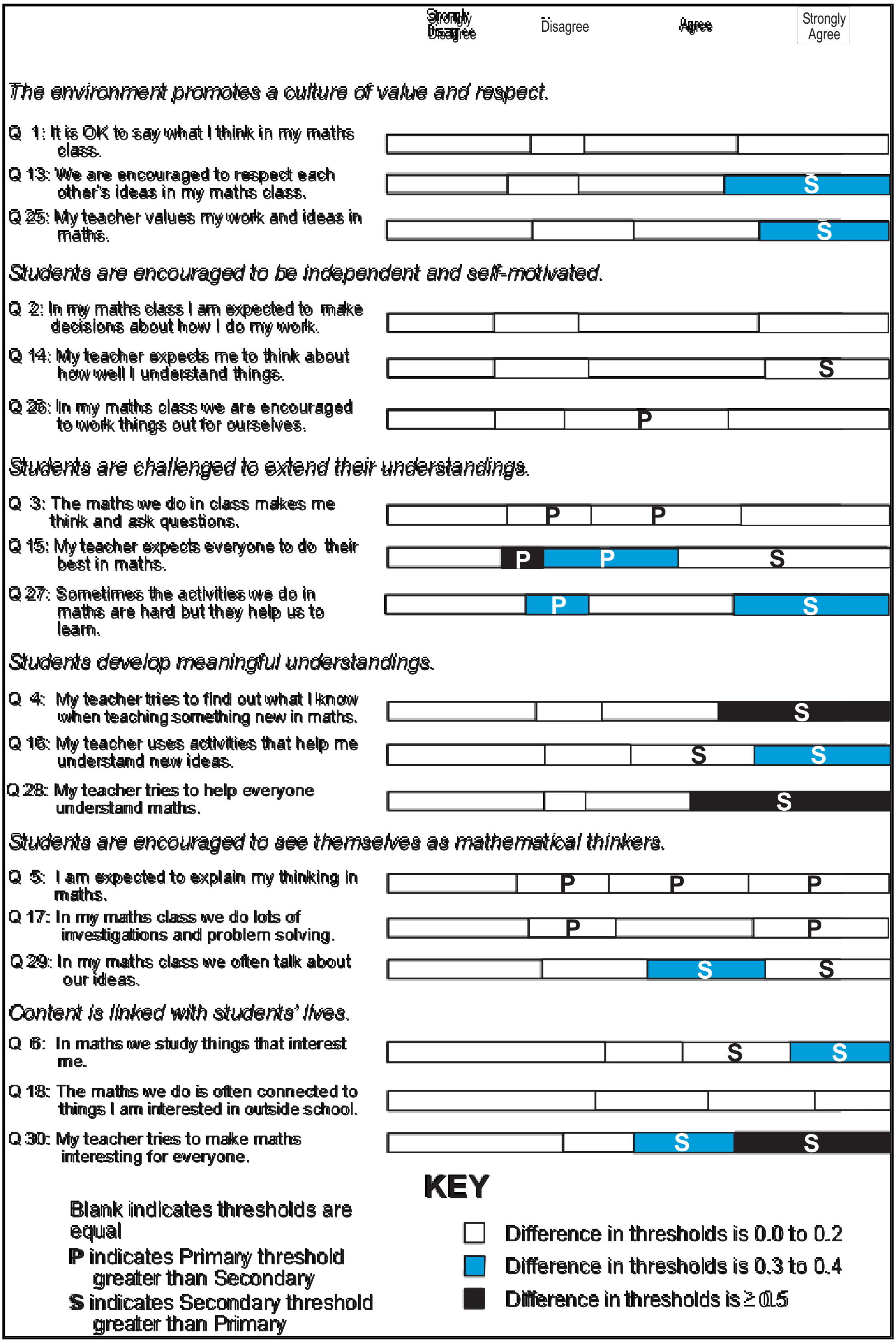


Figure 6: The IMYMS student perceptions reported on an Ordinal Map – part B



An advance on this representation is the Annotated Ordinal Map (Figure 7) in which the bars are labelled P or S depending on whether the threshold is greater, at colour coded difference levels, for primary or secondary students. Thus, strongly agreeing with the statement *My teacher tries to make maths interesting for everyone* is substantially less likely for secondary compared to primary school students.

Figure 7: The IMYMS student perceptions Annotated Ordinal Map.



Further research on student perceptions

Comparing urban with rural, primary and secondary students

In addition to these surveys of students' attitudes to science in the project schools supplementary interviews were conducted with students in four of the project schools. These comprised two urban schools (one primary, one secondary) and two rural schools. (one primary, one secondary). The research methods consisted of:

- Written surveys of perceptions and learning preferences from students
- Group interviews in each school (total of 13 groups of 4-6 students: 3 rural primary, 4 rural secondary, 3 urban primary, 3 urban secondary)

Students were in classes taught by teachers participating in the IMYMS Project. The survey results from the student learning preferences and perceptions surveys from these four schools are shown in Table 7 (first six preferences) and Table 8 (as a percentage agreeing with the statement) respectively.

In Table 8, while there was convergence across all four categories of learning activities – doing worksheets was given third preference in all schools – it is significant to note that only rural students gave high preferences to

- Asking questions about things that interest me
- Watching videos
- Listening to the teacher explain ideas
- Doing projects
- Playing games
- Using computers or calculators

The urban school students all rated doing hands on activities and taking part in class discussions as their first two preferences.

In Table 8 the specific constructs where there is a significant deterioration (difference ≥15%) between primary and secondary school students are shown in bold. In most cases this deterioration is happening in both rural and urban schools, but there are exceptions. These large drop questions tend to be the constructs related to students' views on the relevance of their learning in science, their attitudes to it and their interest in continuing to a science career.

Looking at the results for the specific questions underlying each of the component constructs shown in Table 8, students' perceptions of science are further revealed (rural schools decrease, urban schools decrease). The largest drop from primary to secondary school is in "In my science class we work on projects outside school or have people come to talk to us" (63%, 33%) which tends to indicate that secondary science classes are less connected with the community. The responses to "My teacher tries to find out what I know when teaching something new in science" is particularly worrying as it indicates that secondary teachers are not engaging constructivism in their teaching. Other statements of particular relevance are the students' responses to questions such as "I enjoy the work I do in my science classes" (23%,25%), "I really want to learn about science at school" (18%, 25%), "What I learn in science helps me in everyday life" (15%, 26%), "Learning science at my school is fun" (19%, 24%) and "In science we study things that interest me" (20%, 22%). That for so many statements the secondary students' responses is significantly lower than that for the primary students indicates that something is definitely going wrong in the secondary science classrooms.

Table 7: IMYMS Project students' learning preferences in science survey results (2006)

Student learning preferences in science – activities that are most helpful in learning science	*Rural Primary students N=49*	*Rural Secondary students N=147*	*Urban Primary students N=341*	*Urban Secondary students N=215*
Doing hands on activities	3	3	2	1
Taking part in class discussions	1	4	1	2
Doing worksheets	3	3	3	3
Doing homework				4
Copying notes off the board		2		4
Searching for info using library books	1	1	4	
Watching the teacher show us how to do things			4	
Doing investigations or projects of my own choice	1			5
Searching for info using internet or CD ROM	2			6
Listening to a visiting speaker	1	3	5	

Table 8: IMYMS Project students' perception of learning science survey results (2006)

Student perception of learning science	*Rural Primary students (%)*	*Rural Secondary students (%)*	*Urban Primary students (%)*	*Urban Secondary students (%)*
1 It is OK to say what I think in my science class	92	86	94	88
26 In my science class we are encouraged to work things out for ourselves	91	84	92	81
3 The science we do in class makes me think and ask questions	95	81	86	75
27 Sometimes the activities we do in science are hard but they help us learn	85	71	86	75
4 My teacher tries to find out what I know when teaching something new in science	**92**	**77**	**91**	**73**
5 I am expected to explain my thinking in science	92	78	84	75

29 In my science class we often talk about our ideas	86	73	**87**	**70**
6 In science we study things that interest me	**82**	**62**	**79**	**57**
18 The science we do is often connected to things I am interested in outside school	60	50	**56**	**38**
30 My teacher tries to make science interesting for everyone	94	80	92	73
8 In my science class we work on projects outside school or have people come to talk to us	**87**	**24**	**63**	**30**
20 We learn about ways that science is used in everyday life	**91**	**75**	74	72
32 In my science class we look at things in the news or work on problems that affect our lives	60	50	**62**	**40**
10 I enjoy the work I do in my science classes	**89**	**66**	**87**	**62**
22 Learning science at my school is fun	**96**	**67**	**82**	**58**
34 I enjoy learning science at my school	**96**	**72**	**84**	**62**
11 I really want to learn about science at school	**89**	**71**	**86**	**61**
23 I really want to do well at science	100	94	94	90
12 What I learn in science will be useful to me when I leave school	**91**	**74**	**87**	**65**
24 What I learn in science will help me in the future	81	76	**90**	**68**
36 What I learn in science helps me in everyday life	**70**	**55**	**74**	**48**

These results were presented at an IMYMS symposium by Annette Gough (Gough, 2008, attached) and linked with international trends in student attitudes, and with images of science in popular culture in the developed world.

Student Learning Preferences

Appendices 9, 10 and 11 show similar data for the student learning preferences to those discussed above for student perceptions. This data was mainly generated to inform schools and teachers of student preferences, to use in developing their strategic planning around pedagogy. There are a few trends of interest in the data, however. Some comment on the difference between urban and rural students' preference was given above.

Drawing on the data in Appendix 9, the responses reflect the pedagogies used currently in mathematics and science, and also the different knowledge demands of the two subjects. Hence, playing games is rated highly in mathematics, while doing hands on activities is rated highly for science. These could be regarded as equivalent in some sense as providing the concrete experiences from which ideas are generated in each subject. Using computers and calculators as mediating tools in mathematics does not quite have the equivalent in science, although it is interesting that in the student perceptions survey students of mathematics did not acknowledge the use of technologies as much as students of science. In terms of knowledge generation, one might be tempted to see the mathematics 'doing exercises or answering questions from a book' or 'listening to the teacher explain ideas', contrasted with the science 'searching and collecting information using the internet, or library books' or 'going on excursions' as indicating a much more student centred and exploratory pedagogy preferred for science. However, the contrasting 'copying notes from the board' for science as against 'working in small groups' for mathematics contradicts this. It seems that teacher or text dominated, as against student focused idea generation, play out in different forms in the two subjects.

For the primary – secondary contrast, it seems that in mathematics particularly (see Appendix 10), primary students are much more likely to think teaching and learning approaches useful overall. For mathematics, primary students are more likely to value 'doing activities that challenge me to think' (this was also the case for science, and is a concerning result if it is assumed that challenge is not something secondary students find helpful), 'searching for information using library books' and 'taking part in class discussions'. These are also highly valued for science students, and there is a possibility for primary students that they do not sharply distinguish between learning in the two subjects. For science particularly, one gets the impression that the activities preferred by secondary students compared to primary students involve looking at science beyond the classroom (excursions, talking about the news, using the internet) or socialising with peers (doing hands on activities), whereas for primary students these are more classroom and teacher or text based (challenge to think, doing worksheets, listening to the teacher explain ideas).

These are uncertain trends, but provide potentially significant insights into the differences between the cultures of mathematics and science teaching, and between secondary and primary school students' preferred ways of learning.

The testing program

Results of the testing program across the clusters

As described above, the tests were constructed with two conditions in mind. First, the tests were matched to individual schools' and classrooms' program for the year, following a curriculum audit across the clusters and the identification of a number of CSFII outcomes in mathematics and science to which strands within the tests were written. Each test was given at the beginning and again at the end of 2005, and contained sections tailored to the individual classroom curriculum in that year (three strands), and a section on thinking and working mathematically or scientifically. Christine Kakkinen, a PhD student working within IMYMS to explore assessment of student capability across different dimensions, assisted with the test construction. Her study is described below.

Mathematics achievement tests

The mathematics tests were given to almost 2000 students. The tests contained multiple choice items and also open response items. The open response items were scored according to criteria developed in a workshop with a team of assessors. The method of analysis and the richness of insight coming from these open response items is described in Doig and Groves (2007) which is an attachment to this report.

The results for the mathematics and science testing for all students classrooms were subjected to an IRT analysis using a Rasch modelling technique, so that all the items in each case were put on a common scale. Each item was assigned a threshold logit score, which is on an interval scale and thus able to be subjected to statistical testing. Each student liKewise is assigned a score which is on the same interval scale.

Results for the mathematics testing are shown in Table 9 below. The scores for each cluster on the pre and post tests, the growth over the year, are shown. The standardized effect size is the number of standard deviations by which the population has improved. On this measure, an effect size of 0.3 is generally regarded as a 'reasonable' improvement. Changes and effect size across all clusters are shown for primary and secondary students, and girls and boys.

Table 9: Changes in test scores in mathematics across clusters

Group	N	Pre test mean	Post test mean	Change	Standardized Effect Size	Significance of difference between means
All Cluster A	398/317	0.18	0.43	0.25	0.52	0.00
All Cluster B	204/156	0.1	0.16	0.06	0.12	0.27
All Cluster C	383/326	-0.03	0.14	0.17	0.30	0.00
All Cluster D	87/63	0.1	0.39	0.29	0.62	0.00
All Secondary	354/258	0.25	0.58	0.33	0.73	0.00
All Primary	718/605	0	0.14	0.14	0.25	0.00
All Males	562/460	0.07	0.25	0.18	0.33	0.00
All Females	506/402	0.1	0.29	0.19	0.35	0.00
All Primary Males	378/322	0.01	0.12	0.11	0.20	0.01
All Primary Females	337/282	-0.01	0.16	0.17	0.30	0.00
All Secondary Males	183/138	0.19	0.55	0.36	0.74	0.00
All Secondary Females	169/121	0.31	0.6	0.29	0.72	0.00

The clusters are: A Parkland, B Ocean, C Surfcoast, D Hume

There are a number of patterns in this data worthy of comment. First, there is substantial growth in student achievement across the year, with highly significant improvement in each cluster with the exception of B which is a non-significant change. Second, the scores for the secondary students are well above those for the primary students at both times, indicating secondary students have a stronger grasp of the mathematics. The effect size for this difference is approximately 0.5. While this might seem obvious, it is not always the case that secondary students significantly outperform primary students.

Third, the growth in scores for secondary students is almost three times that for primary students. This may indicate a greater possibility in secondary schools of defining outcome targets and attending to these in the curriculum. It may represent the circumstance that many of the mathematics items were taken from TIMSS population 1 item bank which was written for Grade 4, so that it is possible that year 5 and 6 students may have had capabilities already in these CSF related items and scored relatively high on the pre-test. This would make the improvement harder to achieve. For the abstracted, canonical mathematics represented in the secondary tests, it was less likely that students at the beginning of the year had access to this knowledge and skills. It may indicate that the secondary curriculum is structured more closely to the CSF, given the test items were based on CSFII outcomes statements. It may indicate significantly faster learning of mathematics at the secondary level.

Fourth, there is an interesting result that secondary males start from a lower base on these tests but make up ground by year's end. Perhaps this reflects a more test-savvy approach to the tests by boys.

Fifth, there is variation in achievement across the four clusters. Given the differential improvement of secondary vs. primary students, the difference in effect size for the clusters may in part relate to the proportion of secondary and primary students in the sample in each case. The lack of significant improvement in scores for Cluster B is concerning. It may reflect some circumstance pertaining to the way the post test was administered. It may reflect some socio-economic factors. There is no reason to believe that the difficulties the cluster had with arrangements within IMYMS, described below, would make such a significant difference in student learning.

Science achievement tests

The results for the science achievement tests were more even across clusters. The science tests were more varied between schools, being constructed on a greater number of outcomes with different combinations of outcomes on each test. Almost no test was the same. There were fewer link items which were taken by many students in both primary and secondary, so that the test items and student logit scores are best viewed as separate for primary and secondary students. Table 10 gives the results for the science tests, across all four clusters, males and females, and primary and secondary students.

Table 10:Changes in test scores in science across clusters

Group	N	Pre test mean	Post test mean	Change
All Cluster A	377	-0.65	-0.32	0.33
All Cluster B	191	-0.71	-0.34	0.37
All Cluster C	362	-0.73	-0.41	0.32
All Cluster D	85	-0.70	-0.37	0.33
All Secondary	332	-0.68	-0.34	0.34
All Primary	683	-0.70	-0.37	0.33
All Male	537	-0.70	-0.36	0.34
All Female	478	-0.68	-0.36	0.32
All Primary Male	362	-0.67	-0.34	0.33
All Primary Female	319	-0.68	-0.37	0.31
All Secondary Male	175	-0.68	-0.33	0.35
All Secondary Female	158	-0.69	-0.35	0.34

The clusters are: A Parkland, B Ocean, C Surfcoast, D Hume

In this analysis only students who took both tests were counted, so that N is the same for pre and post test.

In each case the effect size is in excess of 0.6, with a highly significant (at below the 0.01 level) improvement in outcomes for all clusters at primary and secondary level. Unlike the mathematics, the primary and secondary scores cannot be so readily compared because of the small number of link items.

These results can be broken down to compare the improvement for primary and secondary students in each cluster. Table 11 gives these results.

Table 11: Breakdown of test scores for science by cluster and by primary vs. secondary

Group	Pre test mean	Post test mean	Change
Cluster A secondary	-0.64	-0.28	0.36
Cluster B secondary	-0.76	-0.40	0.36
Cluster C secondary	-0.66	-0.35	0.31
Cluster D secondary	-0.69	-0.38	0.31
Cluster A primary	-0.65	-0.34	0.31
Cluster B primary	-0.68	-0.30	0.38
Cluster C primary	-0.75	-0.44	0.31
Cluster D primary	-0.72	-0.35	0.37

There is variation across the clusters in the starting and end of year test scores, and the growth, but the differences do not represent patterns that can be related to known conditions in the clusters. This is perhaps not surprising, given that schools that were less committed to IMYMS and the change process, were committed nevertheless to substantial innovation in their science program.

Assessing student capabilities in mathematics and science

One of the PhD candidates involved in the IMYMS project is Christine Kakkinen, who is focusing on the IMYMS research question:

Q3 How can students' conceptual understandings in mathematics and science and ability to work mathematically and scientifically be assessed reliably?

The data collection for Christine's project has been completed and the data sets and results set up in preparation to explore links between different student capabilities in mathematics and science. The data set is large and complex, and there have been problems during the course of the project that have slowed Christine down. The analysis is well under way, however and will be reported on in Christine's thesis. What follows is an overview of this aspect of the IMYMS research.

Statement of the problem

My research investigates mathematics and science learning in the middle years. An emphasis on rote and superficial learning is regarded as a widespread problem linked with poor classroom assessment strategies. As Stiggins points out teachers are untrained in assessment, despite the fact that assessment plays a critical role in student learning (Stiggins, 2001). In order to improve assessment, Wiliam and Lee (2001) argue that "teachers do not have to choose between teaching well and getting good results on accountability assessments" (p.9). By implementing assessment strategies that reflect many aspects of student capability, an improvement in student learning can be achieved. Black and Wiliam's (Black & Wiliam, 1998b) research provides educators with a good outline of how to use assessment in order to maximise achievement for all students. This involves using appropriate assessment, giving specific feedback, and involving students in the assessment process.

In order to develop high quality classroom assessments, different aspects of capability (such as mastery of content knowledge, reasoning capability, performance skills, and disposition capabilities) require different types of assessment. These aspects of capability will come from the relevant literature, research journals, and information in curriculum frameworks, content standards or statements put forward by states, provinces, national and international organisations, as to what students need to know and be able to do in school mathematics and science.

Whilst there are a large number of previously developed tests of knowledge, understandings and performance, it is more difficult to obtain tests that assess higher-order thinking. Few people have looked for links between teaching and knowledge, understandings and performance.

My research will identify the various aspects of student capability and consider whether all these aspects can be assessed. I will also investigate the relationship between the different aspects and the relationships between mathematics and science.

Overview of the research study

The purpose of the study is to investigate whether there is a relationship between students' understandings, knowledge and performance in mathematics and science. The study will focus on students in the middle years of schooling – Years 5 to 9. Despite efforts to investigate students' knowledge and understanding in the classroom, most research has tended to steer away from performance testing. This research will explore changes to traditional forms of assessment and encourage teachers to think about where to place their emphasis in teaching – on knowledge, on understandings, or on performance – and what sort of balance they can achieve between these three components.

The findings for this research will hopefully provide educators with new and innovative ways of assessing mathematics and science in the classroom. It will also encourage teachers to consider a balance between assessing knowledge, understandings, and performance in mathematics and science. "We need to present science and mathematics as a way of thinking and not simply as an accumulation of knowledge" (Charting Futures conference vision statement, www.deakin.edu.au/arts-ed/steme/conferences/charting-report.php)

There has been a move in the assessment of students over the past few years towards more useful and interesting assessment practices that assess different dimensions of student capability, such as comprehension, higher-order thinking, investigative understandings and attitudes. The initial question guiding my research was "How can students' conceptual understandings and their ability to work in mathematics and science be assessed reliably?" This has been refined to consider assessment of the dimensions of capability appropriate to school mathematics and science in the middle years of schools, and the way these inter-relate.

I chose a quantitative and qualitative approach that sought to investigate the links between different dimensions of student capability and the links between the dimensions of capability in mathematics as compared to science. This included an exploration of the different types of assessment available, and the design and administering of tests of attitude and learning outcomes to students in the project.

As students' mathematical and scientific capabilities develop with the interaction of experience, instruction and maturity, curricular emphasis moves from relatively straightforward problem situations to more complex tasks. The intent is to allow the progression from knowing a fact, procedure or concept, to using that knowledge to solve a problem in complicated or unfamiliar situations. Table 12 contains a description of the seven aspects that contribute to student capability, based on a review of the literature.

Table 12: Description of seven aspects of student capability in mathematics and science

ASPECTS	DESCRIPTION
Factual Knowledge	Knowledge of mathematical and scientific facts and procedures.
Skills and Procedures	The skills involved in carrying out mathematical and scientific procedures.
Conceptual Understanding	The comprehension of mathematical and scientific concepts, operations and relations.
Reasoning	The capacity for logical thought, reflection, explanation and justification.
Inquiry	The capacity to design and implement mathematical and scientific investigations and problem solving processes.
Productive Disposition	To see a sense in mathematics and science, to perceive it as both useful and worthwhile, and to see oneself as an effective learner and doer of mathematics and science.
Nature of Mathematics and Science	An understanding of how knowledge claims are established, and the contexts and ways in which mathematics and science are applied.

These aspects of capability were used to help frame the assessment regimes used in IMYMS, and they are currently the focus of an analysis of the testing and student survey results.

As described above, the data collection was conducted in schools in the four research clusters for a period of one year, 2005. It involved Years 6 and 8 students at the beginning of the year and the end of the year completing paper-and-pencil assessments, and a mid-year performance assessment. These assessments charted student learning over the year and consisted of questions based on CSF Strands and Outcomes the students were studying during the year. In addition, all students completed a written survey in Term 2 of 2005. The survey included items looking at students' beliefs and attitudes towards mathematics and science. "Not only are these characteristics [positive attitudes] desired outcomes of science and mathematics education, but they are widely believed to enhance achievement in these subjects" (Robitaille & Garden, 1998, p.61). In Term 3 selected students from the Year 6 and 8 classes undertook activities to test their "performance" in mathematics and science. This involved students completing various activities designed to challenge them in problem solving, experimental design and analysis.

The analysis of the tests will involve the data being categorized into four aspects of student capability – conceptual understanding, reasoning, inquiry and the nature of mathematics and science. Each item from the written assessments will be linked with one of these four aspects of student capability, in mathematics and in science. Using the Item Response Theory (IRT) software ConQuest, an analysis of the data will provide measures of student attainment on each of these four aspects of student capability for both mathematics and science.

The second part of the analysis related to the data from the written assessments will involve examining the relationship between the aspects of student capability in mathematics and science. For example if a student demonstrates a strong rating in conceptual understanding, will the data reflect the same strength rating with reasoning. This analysis still regards the two subject cultures individually.

The third part of the analysis related to the data from the written assessments will involve seeing if there is any relationship between the aspects of student capability across the subject cultures of mathematics and science. For example, if a student has a strong rating in the aspect of reasoning in mathematics, is the same true for reasoning in science.

The analysis of the performance testing data involves giving the students a rating and also provides detailed information on how they solved particular tasks and performed with these open ended tasks. These data are being used to see if there is a relationship between students' ratings in the written assessments and their results from the performance testing. For example, the data will enable me to examine whether students who perform well on written assessments also perform well on performance tests. Or if students who are not so strong in the written test perform better when more open ended activities and hands on tasks are provided in mathematics and science.

A sample of students who completed the Performance Assessment were interviewed at the conclusion of the test. The interviews have enabled some further insight to be collected about the testing process and how the students performed and solved particular tasks.

Also the teachers involved in the Performance Assessment process will be interviewed. These data were used to see if teachers value the performance testing and whether it enables the teachers to gather information about how students solve problems and work through tasks more effectively and reliably than just relying on data from written tasks. Also, these data may enable me to see whether some students are more suited to tasks involving hands on activities or group work and therefore perform better which may be reinforced by the teachers' comments regarding the performance testing.

A further analysis incorporating all of these data sources will be performed to enable me to see if there are any relationships between the student survey, the written tests and the performance assessment in mathematics and science, and across mathematics and science.

The IMYMS project will create a significant contribution to the field of assessment by devising new and innovative ways of assessing students. Higher-order thinking is one of the priorities of the project, as is identifying other components that impact on student learning. Very few studies have looked for links between teaching and knowledge, understanding and performance, particularly across the separate curriculum areas of mathematics and science.

The findings from my research will assist, I hope, in making links between different aspects of student learning and knowing, and between different dimensions of capability in mathematics as compared to science. The results of this study will also make a contribution to the growing body of knowledge regarding assessment and also provide teachers with interesting processes for testing and mathematics and science. The study will generate information for educators to gain insight into alternatives to their current perspectives of the different dimensions of student capability. Such insights can support or challenge notions of expectations of what students are able to learn and what kinds of instructional activities best promote that learning.

Perspectives on the performance testing

I interviewed teachers concerning their views of the performance testing and the extent to which it had engaged students or provided further insights into their capabilities. We were interested to see the extent to which performance tests might become viable aspects of regular testing regimes.

- The majority of teachers interviewed whose classes participated in the performance testing process strongly agreed that the items could be a useful part of the maths and science curriculum.

  "But I haven't really thought of it as a science experiment and then incorporating the maths aspect in it is great".

- The majority of teachers agreed that the performance item tasks allowed them valuable and helpful insights into how their students were solving the tasks and the processes they were using. *"It definitely shows the strategies they can use".*
- Not all of the teachers were in agreement that it was very clear what the items were assessing. This perhaps reflects their lack of familiarity with the nature of procedural skills in mathematics and science.
- All the teachers agreed that it was important that the aspects of science and mathematics as represented in the performance tasks should be assessed as it gave the teachers invaluable insight into how students learned and what methods of teaching would assist the student to learn more effectively. "Because it helps us to know which are the best ways for those students to learn".
- All of the secondary teachers were in agreement that the performance assessment tasks could be incorporated into their current curriculum. A few mentioned time constraints as a hurdle to incorporating the performance tasks in their classroom.

  "Maybe I do hand feed them a little bit too much information at times whether it is because we are on time constraints I do find myself saying "this is what you should get" rather than letting them investigate a bit more for themselves which would take a little bit more time to do things for themselves but give them that investigation aspect".

- Whilst the primary teachers placed high importance on the performance tasks they felt that it could prove to be difficult to include them in the current curriculum. A few primary teachers did however feel that the new VELS would enable teachers to include more of these types of activities in the classroom.
- Most of the teachers used traditional assessment practices in the classroom but all agreed that by using the performance test tasks would give clearer insights into a students' maths and science processes. *"I think they're better than tests because you can actually see the kids trying to work it out".*
- All of the teachers agreed that the students were interested and motivated by the performance testing tasks..

  "The kids look more engaged". "They're all very keen and eager and they do like to work on the tasks that are all open-ended and non-threatening". I guess at this level (primary) it is important to lay the foundation knowledge but also to keep it fun at the same time and to promote that enquiry". "Yes very engaged and challenged"."The kids who normally, I don't know if they are doing more work or what, but they look more involved in wanting to know what's going on".

The performance testing ran smoothly, in some clusters aided by student teachers from Deakin University who helped with administering and assessing. Teachers, as can be seen from the interview results, responded mostly very positively. Whether such tests can survive the negative factors associated with organisational complexity and resourcing remains to be seen.

Links between Subject Cultures and Teachers' Pedagogies

This section is a report by Linda Darby, the other of the two PhD students involved in the IMYMS Project. Linda's thesis is titled "Relationships between subject culture and pedagogy: Comparing mathematics and science". At the time of writing she is within three months of submitting.

Research focus and questions

As a subsidiary to the teacher change process of the IMYMS Project, my research addresses the fourth project research question:

Q4 What are the links between teachers' pedagogies in mathematics and science?

The research informs the understanding of subject culture by focusing on the individual teacher perspective, that is, how teachers experienced the subject cultures of mathematics and science, and how these influenced their pedagogies. In the analysis, teachers' level of confidence with, and commitment to, the subject, and the pedagogical moves required to present the subject matter, is related to with their views of themselves as teachers operating within different subject cultures. The research addresses the question "What are the relationships between subject culture and pedagogy in mathematics as compared with science?" The following sub-questions guided the research:

- How do teachers experience the subject cultures of mathematics and science?
- How do the subject pedagogies of mathematics and science compare as identified by the intersection of teachers' individual pedagogies?
- How do the subject cultures of mathematics and science shape teaching practice?

Research design

The research participants were seven teachers and their classes from two schools. One secondary school from each of two of the four clusters involved in the IMYMS Project were invited to participate. Schools and their teachers then decided which teachers would be involved in what became known as the "Video Study".

The participants were four teachers from "School A" and three teachers from "School B". Teachers were selected on the basis that they had teaching allotments that included mathematics and/or science subjects. I observed each teacher in two classes, either:

- two mathematics classes (Rose);
- two science classes (Ian, Donna); or
- a mathematics *and* a science class (James, Pauline, Simon).

I used a process consisting of a. classroom observation, b. teacher reflection, and c. and interview, twice in School A and once in School B. This involved classroom observation of two or three consecutive lessons, then filming one lesson for each class. The video camera focused on the teacher as they taught and interacted with students. The video footage of both lessons was returned to each teacher for personal viewing with a set of questions to guide their attention and reflection. Teachers then participated in an individual interview. The interview on the first occasion at both schools explored: the teacher's reflections; their background with, commitments to, and beliefs about the subjects; and any lines of inquiry that were emerging from preliminary analyses of classroom observations. The interview on the second occasion at School A was preceded by an informal discussion with the teacher about the aims and big ideas represented in the unit of which the filmed lessons were a part. The interview then asked teachers to explain how the aims and big ideas of the unit were represented in the video taped lesson (Pauline participated in the informal discussion but not the interview).

After the first interviews, I conducted a focus group discussion involving the four teachers from School A. Discussion centred on three statements arising from data analysis of Sequence 2 interviews, relating to subject specific demands on teaching and learning, translating practices, and influences on teachers. Teacher excerpts from their first interviews and ideas from the literature that related to these statements were distributed to the teachers before the focus group discussion.

In total I observed 28 science classes and 24 mathematics classes, and obtained video footage for 10 science classes and 11 mathematics classes. Other data included: 11 individual interviews, four informal discussions, one focus group discussion and various artefacts (syllabuses and handouts).

Key findings

Lines of inquiry relating to teachers' practices and subject comparisons emerged during and following data generation. I consolidated four themes to isolate different, yet somewhat overlapping, aspects of teaching. The result is an analysis of the personal response of teachers to subject cultural differences that describes how pedagogical practice is shaped by both personal and cultural influences. The themes are outlined below.

The first two themes relate to the differences in what teachers considered central to the subject culture, drawing comparisons between, firstly, the nature of curriculum content organisation across the two subjects, and secondly, the issues relating to actively involving students.

The nature of curriculum content organization

Teachers differed in their representations of curriculum content organisation in mathematics compared with science. In science, teachers consistently represented the curriculum as a series of discrete topics. Movement through the curriculum was seen to involve covering different concepts and skills that may or may not be adequately acquired by students. The task for the teacher was to provide an appropriately engaging and diverse collection of activities to develop conceptual and skill understanding. But this planning was seen to occur without the constraint or imposition of having to prepare students, necessarily, for future science studies. Therefore, the need for sequential organisation was not central in shaping preparation, but was more influential in terms of defining coverage of particular science topics.

By comparison, teachers represented a "continuous" mathematics curriculum. They consistently described mathematics as having a reputation for being a "threatening subject" that requires "catching up" in the event of student absence. Particular demands are consequently placed on student learning, and as such, the need for student support was central for these teachers, such as attending to individual learning needs and constant assessment. Consequently, the nature of the curriculum content organisation in mathematics was central in shaping teaching practice due to the pedagogical need to "fill the gaps" in students' knowledge.

Planning and running mathematical and science activities

The second centralising theme involved the epistemological, pedagogical and cultural demands associated with planning and running mathematical and science activities. Three points are significant.

First, the nature of the activities was different in mathematics and science due to the nature of the subject matter, and teachers' expectations and beliefs about what should constitute the learning experience. Teachers accepted that actively involving students in hands-on experiences helped students make connections between ideas or made the theory more meaningful. In mathematics, activities supported the application of mathematical skills and concepts to a context, or focus on intriguing mathematical patterns through open ended problems or complex problem solving.

Second, teachers' use of and reliance on activity-based pedagogical practices were recognisably different between the two subjects. In science, about a third of class time was spent on practical activities and demonstrations. In mathematics, higher order problems, including single or complex problems or tasks that allowed students to explore mathematical concepts in depth or with creativity occupied about 18% of class time.

Third, in the focus group discussion the teachers discussed the different cultural expectations and traditions surrounding the two subjects. According to the teachers at School A, provision of hands-on activities was supported in science by infrastructure and readily available resources and personnel, and because it was made a priority of the science department to "make science fun" through an activity-based program. Teachers at School A reported that the use of open ended activities and complex problem solving in mathematics was constrained due to limited knowledge of the availability and use of resources, and reluctance by some teachers to move away from text-book based teaching. School B, however, had a strong Head of Department that promoted the use of open-ended problem solving, but time constraints and a packed curriculum restricted the use of such activities.

Conclusion: These two themes highlight important differences in what teachers perceived was central to the subject cultures. There are cultural expectations about what is regarded as suitable and the teachers' responses are strongly shaped by these. I have described these responses as distinct "subject pedagogies" (see Ball & Lacey, 1980), which I characterise as a "Methodology of Support" in mathematics and a "Methodology of Engagement" in science:

- A Methodology of Support in mathematics acknowledges the fundamental importance for these teachers that students are given the best opportunity to be successful in the subject; therefore, support for learning dominated the teachers' approach to teaching and learning. This need for support was seen to arise because of the nature of the sequentially and tightly organised curriculum content which places demands for mastery on students, and hence teachers. While engaging students through activity-based pedagogies was valued, cultural traditions and expectations constrained teachers through a curriculum that is more efficiently taught through pedagogies that focus on the mastery of skills and processes, such as textbook exercises.
- A Methodology of Engagement in science acknowledges that representing the compelling nature of objects and relating these to science ideas, which relies on particular infrastructure and availability of resources, dictates a teacher's pedagogical moves. Teachers relied on practical work to draw students into the subject, to promote interest in science ideas, and to make students' science experiences both meaningful and understandable.

These subject pedagogies represent what might be considered normative perspectives on the reality of mathematics and science teaching as it is enacted and experienced by these teachers, and do not necessarily capture what researchers, policy makers and educators understand as "effective" teaching.

Telling stories to make the subject relevant

A third theme examined how the rhetoric of "relevance" as a generic pedagogical imperative was translated by these teachers into their teaching practice and in their conceptions of teaching and learning in the subject. All teachers believed it was important to relate the content matter to students' lives; however, they seemed to approach this issue of relevance differently, both in practice and in their stated beliefs about what it means to teach effectively. Stories that conferred relevance were used differently by teachers of the same subject, and by individual teachers in their mathematics teaching compared with their science teaching. For example, one teacher was frustrated that she could not tell stories in mathematics as she could in science. Another teacher indicated that stories emanated more easily from students in science than in mathematics. All teachers who taught both subjects understood stories to be more readily available in science than mathematics. Subject epistemologies and purposes accounted for many of the subject differences alluded to by teachers. Teachers' backgrounds (such as whether they had stories to tell), and subject knowledge and commitments accounted for differences between teachers.

I developed four "categories of meaning making" to represent teachers' perceptions of what is needed to be make the subject meaningful and relevant, and how this could be portrayed for students. These are:

- Illustrations of relevance: often referred to by teachers in the interviews as examples of stories they would use to relate the subject matter to students' lives;

- Explorations of familiar contexts: those instances where contexts were used to challenge students to think more deeply about the subject matter;
- Humanising stories of historical and contemporary “heroes”: stories about how historical and contemporary figures have engaged with and developed knowledge over time (only discussed or observed in relation to science); and
- Representations of the human endeavour: examples or stories that described what it means to know, practice and be passionate about the discipline.

Mathematics and science are presented differently in each category, and the stories serve to focus on different aspects of both the subject matter and the place that the subject has in students’ lives. They suggest for students that these illustrations are worthy of attention because of their importance within their lifeworlds. Stories about the discipline and about the concepts in context provide a means to represent this relevance.

Conclusion. As a discourse operating in both mathematics and science, relevance and relating the curriculum to students’ life worlds is well established as being important in making the curriculum accessible and meaningful for students (see, for example, Education Training Committee, 2006). Such a focus, however, depends on teachers understanding how relevance can enter mathematics and science classrooms in a meaningful and appropriate way. Three important findings of this research were:

- The way in which these teachers connected the subject matter to real life illustrates the various meanings that relevance can have. It demonstrates that expecting teachers to make the curriculum relevant is not necessarily unproblematic because the meaning of relevance is not collectively understood, nor is it the same for mathematics and science. For teachers moving between mathematics and science teaching, especially when moving into a subject for which they have limited appreciation or experience, understanding how the subject can be made relevant for their students, and themselves, is of prime importance. Translation of this rhetoric into classrooms depends on teachers being aware of, and having an appreciation for:
    - how the subject matter can be connected with students’ lives, such as through the use of “stories” of relevance;
    - the nature of this connection in terms of what the stories say about mathematics and science; and
    - the aims that are reflected in the connections that they draw, such as relevance to students’ interests and future careers, to citizenry preparation, to understanding the world around them, and to disciplinary practices.
- There were subject related differences in relation to what could be made relevant, and the perceived roles that teachers and students played in contributing “stories” of relevance. For example, the absence of historical stories in mathematics demonstrates a silence and a lack of appreciation for the historical development of mathematical ideas, and how this can inform the learning process. Emphasising this historical development has the potential to depict mathematics as a search for ideas, and not just a utilitarian subject that is only relevant through its direct application to students’ current or future lives.
- Teachers’ beliefs about effective teaching, their disciplinary background, and personal commitments were salient factors in shaping how they related the subject to students’ lives. Therefore, “having stories to tell” is not simply a cognitive issue, but requires a personal response from the teacher. It is likely that evaluative judgements about what might be of interest in the subject shape the teacher’s pedagogical choices; judgements arising from what the teacher knows and values, and which are aesthetic in nature.

The role of aesthetic understanding in the relationship between subject culture and pedagogy

The fourth theme focuses on the role of aesthetics, specifically “aesthetic understanding” (Girod, Rau, & Schepige, 2003), in the ways science and mathematics teachers experience, situate themselves within, and negotiate boundaries between the subject cultures of mathematics and science. The theme outlines teachers’ commitments to the discipline, subject and teaching by exploring three elements of what it means to appreciate and have an "aesthetic understanding" of the subject. Teachers talked about being passionate about the subject they were teaching, their students, and students engaging with the subject matter; for example, "I tell them I love maths". They expressed a flamboyance in their teaching when they had a more sophisticated understanding of the topic, they had experiences they could draw from and stories to tell, and when they were interested in it; for example, "I have done dolphin research so I was able to talk about that in more detail than I can talk about physics". They also aligned themselves with subjects they were most confident with; "I am a science teacher more than a maths teacher". The framework of aesthetic understanding captures these personal elements of teaching by describing: what it can mean for a teacher to be compelled by and passionate about the subject and students engaging with the subject, to have a coherent and unified sense of what the subject is about and how to bring it to life for students, and to be transformed by what they know and believe in a way that aligns them to personally and professionally identify with the subject.

Conclusion: This theme has shown that teachers have a stronger sense of themselves in relation to a subject that they have an aesthetic understanding of, and that problems arise for teachers when they lack such aesthetic understanding; problems such as feelings of incompetence, frustration with not being able to adopt approaches that work well in one subject but not another, and difficulties in elaborating on subject matter to enrich students' learning experiences. A theoretical framework of aesthetic understanding helps to identify the barriers, disconnections, and lack of appreciation that may prevent teachers from personally engaging with the subject, and inevitably impacts negatively on the quality of teaching.

Implications and future research

Implications for teachers teaching out-of-field

This research has shown that problems can arise for teachers as they negotiate subject boundaries. Two of these are discussed below as implications of this research, as are suggestions for future research.

1. *Problems with lacking aesthetic understanding:* The problem specifically for the "untrained" mathematics or science teacher is not simply a lack of content knowledge. This research emphasises the importance of teachers being committed to the subject, being able to identify with it, and knowing how to bring the subject matter alive for students. Efforts to improve mathematics and science teaching should be premised on the understanding that an aesthetic appreciation for mathematics and science is just as valuable as developing conceptual and pedagogical knowledge associated with the subject.

2. *Problems with not understanding subject traditions:* Teachers teaching a number of subjects are expected to understand pedagogical traditions in each subject, including basic assumptions that underpin these traditions and expectations. Out-of-field teachers may be less aware of the demands imposed by the subject culture, and may be ill-equipped to appropriately filter, or respond to the subject pedagogies, such as the "methodologies of support" and the "methodology of engagement" presented here.

   In addition, being aware of the demands of the subject can enhance a teacher's ability to seek appropriate alternative practices. This is significant for a number of reasons. First, subject pedagogies within the school have the potential to shape the practice of a novice or out-of-field teacher, particularly if those traditions and practices are deeply rooted in the school subject culture. Teachers who are flexible and embrace innovation and change are more likely to be successful in countering prevailing subject pedagogies that perpetuate traditional and ineffective teaching practices. Second, knowing what works and what does not, and an appreciation for how the subject both affords and limits change is required before a teacher can contribute meaningfully to conversations about curriculum development and innovation.

3. *Future research into experiences leading to confidence for out-of-fielders:* The data has shown that having a background in a discipline is likely to equip teachers with the disciplinary knowledge to draw on in their teaching and an appreciation and enthusiasm for the subject that can be transmitted to students, qualities that are often used to define effective teachers (Darby, 2005) and potentially lacking for teachers teaching out-of-field (Ingvarson, Beavis, Bishop, Peck, & Elsworth, 2004). Other research shows that, while a teacher's practice is dependent on the experiences that the teacher has had with the subject or discipline, these experiences are not necessarily related to exposure at university level. For example, other factors,

such as career trajectory (Siskin, 1994) and professional development (Tytler, Smith, Grover, & Brown, 1999), have been found to be cogent in determining how teachers approach teaching and learning. These research outcomes highlight the importance of paying attention to teachers' experiences of the subject they are teaching. Evident also is an assumption that teachers can be inducted into the culture of a subject through their experiences, and that, with further training, teachers can improve their competence and confidence in teaching a subject for which they have previously had limited background. Further research is needed that problematizes the assumption that disciplinary training automatically and alone leads to effective teaching. Such research could explore those experiences that teachers teaching-out-of field believe are instrumental in developing confidence and competence in their teaching.

Contributing to the debate about generic and subject specific pedagogical description

4. *Subject specific descriptions of pedagogy are more useful and informing of subject teaching:* In the face of the recent move towards generic pedagogical descriptions, it is important for teachers, educators and policy makers to understand how the subject plays a role in determining pedagogy. Often these links are made during teacher training. While descriptions of generic skills, knowledge and attitudes associated with teaching are important and have the potential to provide a strong foundation for all teachers, my research implies that translating these from subject to subject is not necessarily straight forward. Initiatives to improve teaching at the secondary level in particular should be informed by an understanding that any pedagogical skill needs to be translated in the process of subject teaching. Consequently, professional support programs, such as mentoring or coaching, are likely to be more beneficial if subject matter specialists are used or provide substantial input.

5. *Future research on successful translation of generic pedagogy:* Further research is needed to develop rich descriptions of those knowledge, skills and attitudes that teachers bring into their out-of-field teaching from their in-field subjects, particularly in terms of how the demands of the subject come to bear on their translation for teaching in the out-of-field subject.

Cultural and individual differences informing the change process

This research uncovers significant differences in what was considered to be at the core of the teaching experience for these teachers. On the one hand are the cultural differences that make the subject identifiably mathematics or science. In mathematics, supporting students to move through sequentially organised curriculum content was an imperative driven by long standing traditions that seemed to work against teachers' attempts to use more innovative higher order problem solving activities. In science, the goal of compiling a coherent sequence of activities was driven by an imperative to engage students, but which could undermine a focus on high level conceptual understanding. A common imperative to link the subject matter to students' lives was shown to be translated differently in mathematics and science.

On the other hand, individual differences between teachers yield the diversity of practices that we see across schools and within schools. In my research, these differences were evident in a number of ways. Teachers related practical work to theory differently. The two schools approached open-ended problem solving differently resulting in different degrees of latitude for teachers to move away from traditional teaching modes. Teachers made pedagogical decisions based on their set of beliefs, experiences, knowledge and preferences in relation to the subject, and teaching and learning generally. Teachers' passions, coherence in their understanding of content and pedagogy, and their identity, were shown to be integral to the way the teachers positioned themselves in relation to the subject, and in shaping their confidence and competence.

6. *Describing subject and individual pedagogies to inform teacher and school change:* Pedagogical descriptions that represent both the subject pedagogies and individual pedagogies inform teacher and school change in a number of ways. First, diversity of practices amongst staff in a school act as a pool of perspectives, experiences, and possibilities from which innovation can emerge. Second, identifying cultural practices that staff have in common, and assumptions underpinning these, has the potential to highlight strengths and weaknesses, and connections and disconnections, associated with the prevailing subject pedagogies. This is a first step in moving towards establishing common goals for school and teacher

change. Research has shown that a cohesive subject department is more likely to produce positive student outcomes than a subject department that is disparate in terms of goals and beliefs about what is effective teaching and learning. Understanding the local school science and mathematics cultures is the first step in knowing where change is needed, and how to effect school wide change.

Conclusion

This study has shown that description of what it means to teach a subject cannot be approached at a generic level but must be attentive to both the knowledge that makes a teacher competent in their teaching, and what it means to have an aesthetic understanding of the subject. Preparing teachers to teach a subject or supporting teachers to teach out-of-field becomes a process of not only building their knowledge of content and pedagogy or assisting them in developing pedagogical content knowledge; nor is it simply enculturating them into the ways, traditions, beliefs and practices associated with the subject; but it is also be a process of becoming where teachers increasingly see themselves in relation to subject matter ideas.

Innovation and change in the four clusters

Across the clusters during early 2004 there were many meetings of IMYMS coordinators and cluster meetings involving the Deakin team, to clarify the nature of the strategic planning processes and undertake the auditing processes. The process was supported by the first network meeting held in March 2004 (see Appendix 2 for a project timeline) which took coordinators through a Leading Change workshop.

A range of audit instruments were used within the clusters to inform planning. The key audit instrument was the component mapping, which had a dual role of providing formative information for schools, and data for the project to track change and interrogate pedagogical practices. The student survey instrument was given as a scannable sheet and this was processed by the Deakin team and returned to schools to enable its use for informing planning. There were a number of audit instruments used by schools but not collected by the team. These included the strategic planning audit and curriculum audit for schools, and a cluster processes audit for cluster educators.

An example of schools' analysis of these instruments is given in Figures 8 and 9 below, for Hume Secondary College. The curriculum audit instrument is based on the IMYMS Components and asks teachers to analyse their curriculum documents against these.

Figure 8: Curriculum audit data arising from a school team meeting

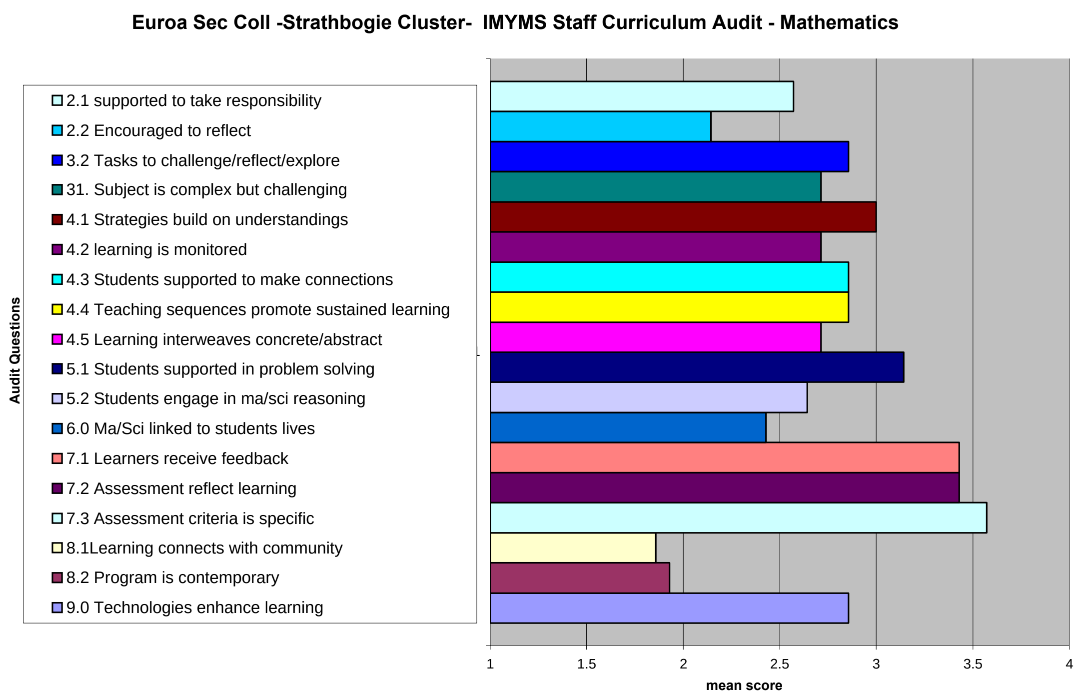
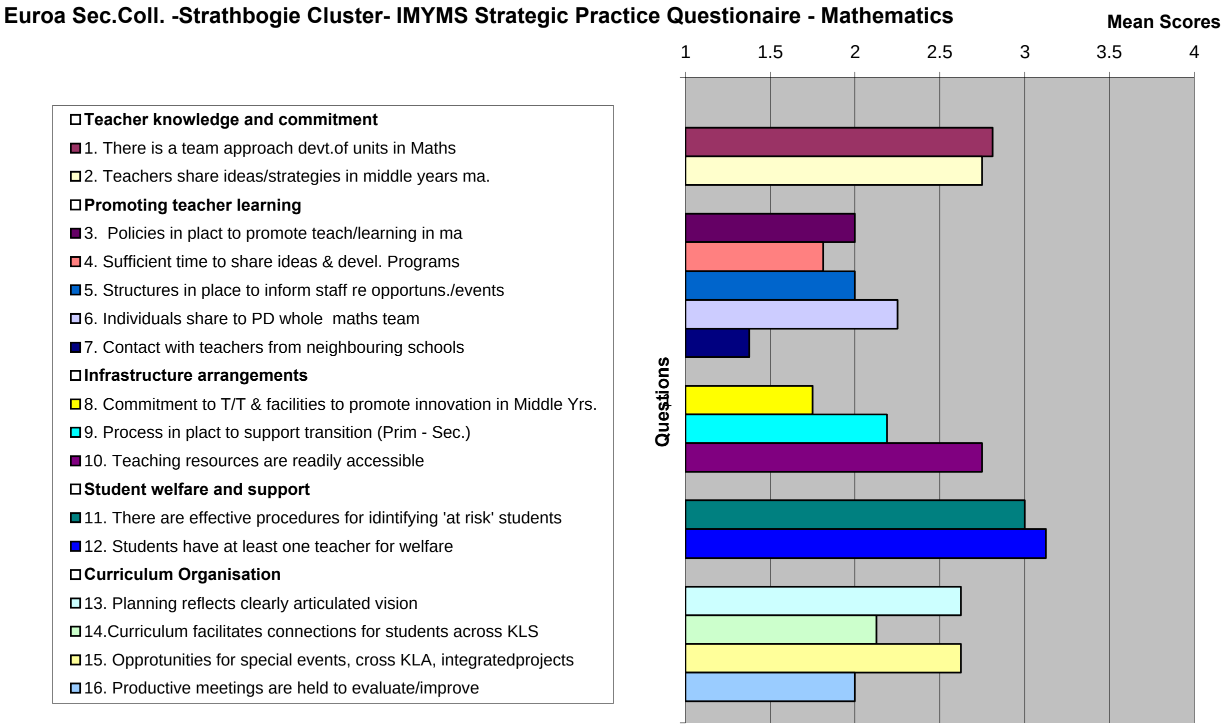


Figure 9: Strategic processes audit data arising from a school team meeting

Generally, the cluster educators were involved with helping guide each school's strategic planning process and forging these into a coherent plan for the cluster. To varying extents, the cluster strategic plans are coherent documents, but for the larger clusters there was considerable variation in what individual schools were doing. Bringing initiatives into a coherent framework required skills and initiative and attention to detail, on the part of the cluster educators. In most clusters the strategic plans of the schools had some individual, and some cluster wide elements. Thus, for Surfcoast, the whole cluster was involved in a specific mathematics professional learning initiative that enabled the primary schools in particular to share resources and experience, while science initiatives were more the province of individual schools.

A further complexity related to the fact that for each cluster, IMYMS was only one of the initiatives committed to by the Innovation and Excellence program, and cluster educators had other responsibilities than mathematics and science. Thus, some cluster initiatives represented innovation that was wider than mathematics and science but included these. In only one case – for the Surfcoast cluster - did the cluster educator have a strong mathematics/science background. That is not to say however that the cluster educators were not committed to IMYMS or effective in its running. Initiatives in Parkland for instance, focusing on assessment rubrics or teacher reflective journals, have provided significant impetus in science and mathematics.

Another complexity related to the fact that a number of schools in these clusters had previously been involved in the SIS project, and had a history of strategic planning in relation to science, and ongoing initiatives in science. These fed usefully into IMYMS, and provided a source of teacher expertise in the process of change, in discussions during network meetings. In some cases a cluster focus on mathematics was accompanied by ongoing innovation in schools in relation to science. In this section, an overview of the main strategic directions and activity is given for each cluster, to provide a sense of what happened 'on the ground' with IMYMS



schools.

The final complexity relates to the very real difference in perceptions of needs and in the cultures operating in primary compared to secondary schools. It often proved difficult for cluster educators to forge a common direction that included primary and secondary school needs, and there was at least one instance of a secondary coordinator declaring that the cluster meetings were not very relevant given most of the conversation concerned primary schools. It might seem to be a powerful strategy to bring secondary and primary teachers together to combine their strengths and knowledge and share pedagogical insights, and indeed this did lead to worthwhile conversations and sharing of initiatives in a number of cases. The reality, however, is that primary and secondary teachers of mathematics and science work in very different contexts that generate different concerns, and have quite different histories of commitment to the subject and to educational purposes more generally. This needed to be accepted by the cluster educators, in managing the conversation and initiatives.

Snapshot across the four clusters

Data concerning the clusters was of a variety of types. During the project, a broad understanding of the progress of each of the clusters was constructed from observations and conversations with cluster leaders, coordinators and notes taken at cluster meetings and network meetings. A more in depth analysis of the cluster processes and outcomes is provided in following sections of the report, but in this section a snapshot of each cluster is given, at the level of broad arrangements and progress and significant contextual features. The purpose of this is to provide an understanding of some of the affordances and constraints, and events that shaped the way IMYMS proceeded in the four clusters. A listing of the clusters and schools is given in Appendix 1.

The Surfcoast cluster consisted of Surfcoast Secondary College, a well regarded secondary school on the outskirts of a major regional centre, and six primary schools scattered in the south west region of Victoria. The schools were within a half hour drive of each other. The cluster educator had a strong mathematics-science and environmental education background and was very active in calling meetings and supporting the schools. His office was in Bells PS, which had been a SIS school with a history of science innovation. The major initiative that occurred across the cluster was a mathematics professional learning program organised by a well regarded mathematics educator, and this had the effect of allowing significant sharing of ideas and resources particularly in the primary schools. The leadership in the secondary college were very keen to use IMYMS to institute change in pedagogical practices. The mathematics and science coordinator was newly installed and had a strong belief in activity based science and mathematics that was somewhat at odds with the wider pedagogical focus of IMYMS, and the tension implicit in this was an influence in the way the project progressed in that school.

The Parkland cluster consisted of Parkland HS and five primary schools in reasonably close proximity. The coordinator had been a principal in a local school, who had experience in managing change and close knowledge of the schools in the cluster. He instituted a range of initiatives that involved cross-school planning groups, and there were a number of initiatives that were very successful in improving classroom practices. A number of the schools had been SIS schools who had prior experience of the strategic planning process. Parkland HS had been a SIS school. The mathematics coordinator at Parkland HS had been working to institute substantial changes to the mathematics curriculum towards greater representation of problem solving, and IMYMS supported this to happen in a more recognised way. A powerpoint he presented at the March 2005 network meeting is included as an attachment.

The Hume cluster consisted of Hume SC and three local primary schools, two of which (Lesley and Reilly) were quite small, in a rural area 2 hours drive from Melbourne. The IMYMS team at the secondary school in particular was active and well organised from the start of the project. The cluster educator retired at the end of 2004 and was replaced by another educator who therefore came into the project without a history of knowing the processes and history of the project, but who nevertheless represented the project strongly in a variety of external forums. Over the course of the project the three primary schools became effectively inactive for a number of reasons, the difficulty of sustaining momentum in a small school being one of these. Much of the activity in the secondary school was driven by the IMYMS coordinator who had a history of innovation in science and mathematics, and the mathematics coordinator. There were a number of effective initiatives during the project based around community links and problem based learning in particular.

The Ocean cluster consisted of two secondary schools – Ocean SC and River SC – and 10 primary schools spread over a driving distance of almost two hours. The distance from Melbourne, and the distance between what were in effect two local school clusters, presented problems from the start, and these were compounded when the cluster educator resigned during the first year, and was replaced by two successive coordinators who were committed but lacked time to really provide the attention needed. Thus, it was difficult at a number of levels to maintain effective communication with the cluster and within the cluster. During the first year progress was made on strategic initiatives and there were some interesting innovations planned between some of the small schools on the Western side of Ocean in particular. These faltered, however, because of lack of time to meet and share resources. Coupled with these problems, there was a complete change of the IMYMS coordinators in all the schools in the cluster between 2004 and 2005 which meant a significant loss of history. During 2003-2005 the secondary school was in the middle of developing a new science curriculum with a range of innovative units, and also preparing for moving to offering year 11 and 12 subjects. In this busy and committed environment, teachers did not manage to align the IMYMS strategy successfully with their planning process, and an opportunity was missed there in the period of leadership vacuum. Thus, the data from the Ocean cluster is incomplete and does not reflect the Strategy in the way it was intended. There are, however, interesting insights about the process of change and about the difficulties experienced by rural schools, coming from this cluster.

Surfcoast Cluster

A variety of initiatives focusing on teaching and learning of mathematics and science were listed in the school reports in 2004 and 2005, with good progress being reported on a number of these. Table 13 lists those initiatives occurring more than once cross the cluster. .

Table 13. Frequency of initiative type mentioned in school reports for 2005 from Surfcoast Cluster.

Initiative	Number of instances reported
Establishing links with the wider community (science)	5
Integrating open ended investigations and problem solving (mathematics)	3
Establishing links with the wider community (mathematics)	3
Increasing the use of hands on activities, promoting questioning and investigating, and raising profile (science)	3

The initiatives outlined in Table 1 are taken from the 2005 school reports because three of the five schools that submitted their reports carried their initiatives over the two years. Establishing links with the wider community was the most frequent initiative in science. In mathematics, community links and integrating open ended investigations and problem solving were the most frequent initiatives.

The main achievements mentioned in the 2005 reports are shown in Table 14.

Table 14: Frequency of mention of types of achievement for 2005 from Surfcoast cluster

Type of achievement	Number of instances reported
Better planning (e.g. complete scope and sequence charts, two-year cycles, use of teams – e.g. middle years)	4
Whole cluster working on common activities	4
More open ended tasks and investigations in maths	3
More time allocated to planning	2
Relevant staff professional development	2
Increasing profile of project within the school community	2
Improved teaching including: confidence and enjoyment in teaching, strategies including assessment, improved student engagement	4

To provide a picture of how schools were creating change, two schools are outlined below.

Mount Daniel Primary School ran two initiatives, one for each of mathematics and science. These initiatives were carried out over the two years. Their mathematics initiative involved integrating open-ended investigations and problem solving in mathematics and attempts to relate mathematics to real life. This was done in 2004 by introducing the program "Earn and Learn" to model small business ventures. These lessons were very popular with students as they enjoyed the problem solving aspect of the program. In 2005, professional development with Mick Ymer assisted teachers in developing a two year plan for mathematics and working with other schools across the cluster to develop common units of work that had a strong emphasis on investigations in mathematics. This action had the advantage of sharing the work load between teachers, and making mathematics activities more interesting and engaging for students. Teachers have enjoyed this cluster approach to planning.

> *Through IMYMS we are organised to share planning and resources across the cluster. For example a Maths PLT unit. We have gone from text based maths to problem solving activities. … Recent cluster-based PD has strengthened maths.*
>
> (Mt. Daniel teacher interviewed about PD in rural schools)

Their second initiative involved making links with adults working in science related careers and discussing the news during lessons. Activities that the school implemented in 2004 to lift the profile of science include establishing science on the news board, involving students in Water Week activities, a whole school excursion to Science Works, and sharing of ideas with teachers from other schools. The excursion in particular was successful, with follow up discussions in class. In 2005, parents with science related careers gave talks and ran workshops for students. This had the effect of changing stereotypes of scientists and exposed students to areas of science with which they were not familiar.

Joining with other schools in the cluster through the Professional Learning Teams was considered to be highly advantageous in the planning and sharing of resources in both mathematics and science. Difficulties arose with the changing of staff from 2004 to 2005, resulting in teachers requiring training, especially in the "Earn and Learn" program. The school also found that, although the news board was a good idea, it would work better if it was integrated with other literacy activities in the main classroom rather than the science room.

Seachange Primary School ran three initiatives each year. One was to involve teachers in a cluster planning team, which ran across the two years. An initiative involving making links with the local secondary school through chemistry days, table tennis and school performances at the secondary school ran in 2004 only. Availability of transport and time presented challenges, with the primary teachers more enthusiastic about creating these links than the secondary teachers.

Fostering of community links through various environmental programs were the focus of the other three initiatives. These were established prior to the school's involvement in IMYMS. In 2005, environmental science was promoted during camps, excursions, and visits to other schools to view their programs. Although these activities were time consuming and logistics of transport proved challenging, they achieved greater whole school and cluster focus on local and environmental issues. In 2005, these programs were extended into two initiatives involving various propagation and revegetation projects and setting up of an environmental centre that involved links with a local environmental group. Parental involvement and an increased sense of responsibility and care for the local area resulted.

Like the teachers at Mount Daniel Primary School, teachers from Seachange Primary School valued the support from the cluster in professional development and planning. They found that an important outcome was the positive outlook and more uniform approach to planning using the cluster for support. Limited involvement from secondary teachers presented a challenge.

Some comments from the Surfcoast Cluster teachers:

"The component mapping has probably been the main contribution to any IMYMS generated change to our teaching/planning as it has made us question and review our approach to teaching and learning."

"I have changed the way I plan mathematics lessons and using the Mick Ymer two year plan has enabled me to use a more investigative approach"

Parkland Cluster

The most common initiatives mentioned in school reports in 2004 and 2005 are listed in Table 15. The rubrics initiative ran over two years at three schools, resulting in their initiative being counted twice. This has resulted in a frequency of seven instances where this initiative was mentioned.

Table 15. Frequency of initiative type mentioned in school reports for 2004 and 2005 from Parkland Cluster

Initiative	Number of instances reported
Use of rubrics	7
Negotiated curriculum (science)	4
Reflective learning (mathematics and science)	4
Increasing the use of ICT in science	3
Diverse and authentic assessment, (mathematics and science), at	2

A Professional Action Learning Team (PALT) was developed to include teachers from across the cluster. Cluster-wide professional development activities offered by PALT relating to rubrics, negotiated curriculum, and reflective learning resulted in most primary schools developing initiatives focused on these areas.

Banks, *Parkland East* and *Halliday Primary Schools* developed initiatives in 2004 and *Parkland Primary School* in 2005 that focused on introducing rubrics to enhance student learning in mathematics and science. All schools found that students appreciated the use of rubrics for teacher-, peer-, and self assessment purposes. *Banks* reported that there had been greater understanding in the development of more explicit criteria and how these can be used for open-ended tasks.

> *We started using the rubrics with kids to get them use to these kinds of things and using them as part of self assessment … this one is used for web pages. They actually found they really enjoyed it. This made very explicit what they were trying to achieve and break down the tasks - what you need to do to get a fantastic mark.*
>
> *We found out rubrics made our teaching…its was more of a thoughtful process in our planning, about what we really wanted to achieve and … [provided a] more explicit sense of how they could go about achieving that.*
>
> *Also the feedback, to parents and to students. We found a big jump in our results especially the parents survey. We found our feedback was pretty low level assessment of volume and we made a massive jump in that.*
>
> Cluster educator, Final network meeting

Negotiated curriculum became an initiative in 2005 when teachers from across the cluster developed science units where some aspects were negotiable, including "What scientists do," and a unit on the human body. All schools reported improved levels of student engagement. *Parkland Primary School* reported that motivation to complete work in the set time had also improved. The logistics involved in getting schools together proved to be a challenge.

Initiatives relating to student reflective practices were implemented at four schools. This was a focus at *Parkland East Primary School*, with all teachers participating in a school-wide professional development with Carolyn Coil. There has been moderate progress with only some teachers successfully implementing the ideas into their classrooms. Other schools showed little direct progress towards implementing this initiative.

In 2005 *Parkland High School* made significant developments in mathematics in the area of assessment including pre-testing, rubrics and rich assessment tasks. There have been discussions and trials, with mixed levels of commitment from staff to trial different assessment practices in mathematics. An initiative increasing the use of ICT in science has involved trialing robotics at Year 8 level. The school is seeking funding for new data logging equipment, having had a positive response from teachers to professional development in the use of data loggers in 2004. A powerpoint presentation by the IMYMS mathematics coordinator at Parkland High School is included as an attachment to this report. It talks of the problem solving focus, the strategic actions taken by staff, and the student and parent outcomes.

The Cluster Coordinator reported that “The IMYMS project has given the cluster a working model to implement research methodologies and has been a vehicle for raising expectations and levels of knowledge and expertise in the use of such models.” He also felt that “The cluster is working both cooperatively and collaboratively through a number of examples of commonly planned activities. … Teacher interaction through participation within these teams has been exceptional leading to changing attitudes, increase in skills and knowledge, and greater professional fulfilment.” In terms of enhancing student engagement, the coordinator stated that “Anecdotal evidence suggests that student engagement has improved as a result of specific cluster initiatives, in particular the use of a negotiated curriculum model.”

Hume Cluster

The Hume cluster consisted of Hume Secondary College, and Lesley, Reilly and Hume Primary Schools. Most of the initiative in the cluster was centred on the secondary college, led in particular by a very active IMYMS coordinator with a brief for both science and mathematics at junior secondary level, and a mathematics coordinator at the upper secondary level. The smaller primary schools’ commitment waned over the two years partly because of the difficulties in generating a sense of collegiality in a very small school and across the cluster. One school closed down due to low numbers at the end of 2005. The schools built their initiatives largely around common themes:

1. Problem based learning (PBL: 3 schools): This was a prior interest at Hume SC and led to professional development program and curriculum days in the schools. The primary schools planned to incorporate this strongly in their curricula but reporting on progress was minimal in 2005. Hume PS had students creating digital material in relation to PBL At Hume SC two problem based units were developed, in ‘natural habitats’ and ‘space’, and students worked in groups on problems within the units presented at an exhibition to panels of local community members.

2. Community linked projects (2 schools): Hume SC ran a ‘weed warriors’ program with the Department of primary industries, local landcare groups and farmers. As part of the program students successfully bred a biological control agent and released it at local sites to curb the spread of a noxious weed. This work was reported by Michele B at an IMYMS network meeting and that presentation is included as an attachment. Lesley PS developed links with the Hume arboretum to institute a grounds development program, but it was uncertain from later reports whether this had progressed substantially.

3. Transition initiative: *Hume SC* developed student portfolios on science laboratory skills for Year 6 students to provide information for Year 7 teachers as a transition initiative.

4. Assessment: *Hume PS* worked on DART assessment and self assessment in mathematics, and also introduced innovations for developing students’ thinking skills.

Hume SC had instituted a comprehensive diagnostic mathematics assessment program prior to their involvement in IMYMS, and this was continued as part of the IMYMS project. It involved a set of strategies for identifying and supporting students at risk. In addition to this, the curriculum at years 7 and 8 was organised within middle years principles of minimising the number of teachers that students interact with and providing significant personal support to students.

> *Another that has worked well …we have for a few years worked in small teams of teachers so for example my year 7 team, I teach maths and science. Other teachers soc and English maybe so the kids have only got 4 or 5 main teachers instead of the usual 11 or so. So we reduced the amount of teachers to kids. Have the integration process and that's evolved over about 3 or 4 years or working in the primary schools. Going out. We did a lot of work with shadowing. Primary school teachers they came up with us so we have good involvement with our primary schools in developing fairly good curriculum I think. We're just looking now in continuing the process. We're doing SIT now so we're doing the SIT process but we're looking at doing POLT right across the school anyway.*

IMYMS Coordinator, Network meeting

The mathematics and science subjects were integrated at these levels and this allowed them to experiment with problem based learning and community linked projects as part of IMYMS.

> *With the maths, we've made it as part of reflective learning with year 7 and 8 in particular, so we've introduced that as part of normal…so that the kids are actually keeping like a journal with their books of what we've learnt. From an activity and every part of testing and that. We use that sort of reflection. So getting them to think about what they have learnt. Standard testing. We've done more hands on stuff in year 7 and 8. And followed more the middle years numeracy recommendations. More integrated work. … so year 7 has just finished an integrated unit with PE. They got figures tested in PE and then maths we did speech excel graphs and then statistical work - in maths So what we've tried to do in maths is to do with people. Integrate with those subjects. To link things better and show them that maths is a bit more meaningful*

IMYMS Coordinator, interview

Thus, IMYMS became a significant support for a number of emerging innovations at the school, providing some status and publicity to spur these projects which were aligned with the IMYMS Components. It had been intended that these innovations would spread into years 9 and 10 mathematics in the school, which is organised along more traditional lines. Progress on this aspect of the innovation was not clearly reported.

Ocean cluster

The Ocean cluster experienced a number of difficulties with turnover of personnel, and problems with the geographical spread of the cluster in that distances between schools were large and made communication difficult. This meant that the impact of IMYMS was limited, compared to other clusters, and information from the cluster was not comprehensive which make reporting difficult. Nevertheless, there were a number of high quality projects within the cluster that made good progress. These were seen by staff as running parallel to IMYMS, but nevertheless were supported by the IMYMS processes.

Ocean Secondary College was in the process of substantially revising its science and mathematics unit offerings over the course of IMYMS, and preparing for the development of year 11 and 12 subjects for the first time, so that a lot of the energy of the science and mathematics coordinators and staff was focused on resource production. As part of IMYMS, OSC focused on developing units that were connected to the local community, including a unit on water connecting to Waterwatch and Gippsland water. They also instituted an initiative in which activities encouraging self reflection were built into the Year 7 program, including the encouragement of student self assessment.

Ocean PS as part of IMYMS developed and ran units of work on chemical reactions and earth and space, with a specific focus on science vocabulary. During 2004 they report a number of successful meetings where planning took place. They were successful in this initiative, but noted in their 2005 report that having a new coordinator and teacher at this level made it difficult to maintain this initiative.

Timber PS was one of a number of small schools that initiated new curriculum innovations with the expectation of working with other schools, but distance and time in the end proved overwhelming. Tambo nevertheless successfully purchased computers and mathematics software which the students 'loved'. There were plans to share science activity plans and equipment across a number of these small schools, and a number of meetings were held early in the project. However changes in the cluster coordinator, and an almost total change of school coordinators between 2004 and 2005 meant that progress on these initiatives was difficult to achieve.

Changes in team processes

One of the key findings of the SIS research project was that the strategy encouraged a substantial improvement in team processes. This came from a base of quite low levels of curriculum and assessment planning and discussion of teaching and learning principles and strategies. In IMYMS, as part of the final questionnaire, school coordinators made judgments about how their schools' team processes had changed over the project. The results across the four clusters is shown in Figure 10

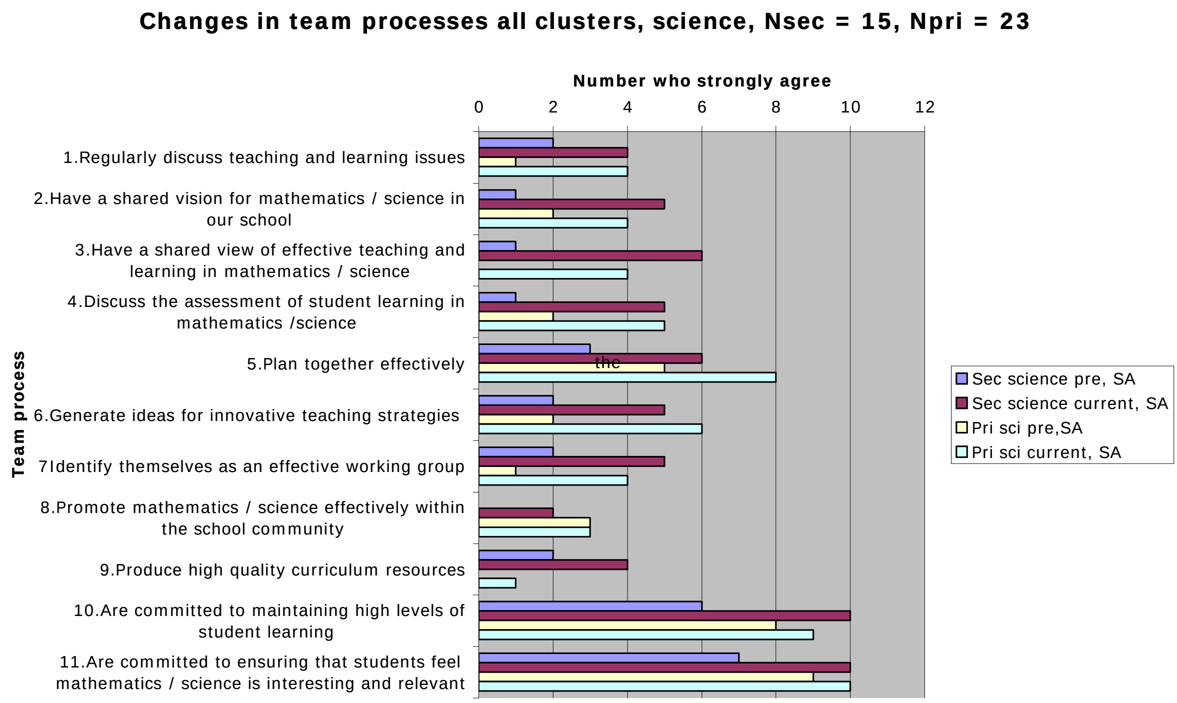
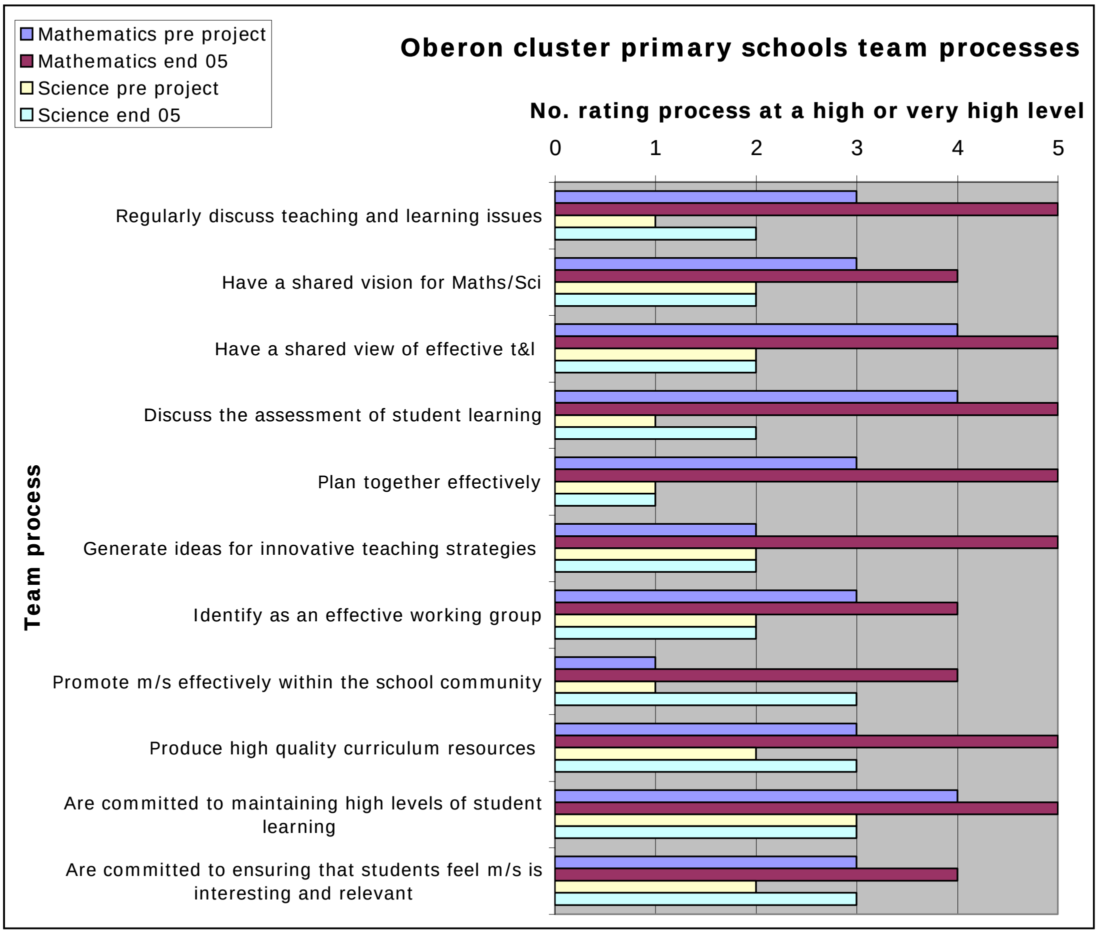


Figure 10: Changes in team processes, from the 2005 questionnaire for teachers across all clusters

While the numbers are not large, it is clear that at least for some schools there has been substantial increase in the planning and discussion of teaching and learning around mathematics and science, for both primary and secondary schools. Changes in team planning are of course a function of the particular innovations focused on, and there is evidence of this link in the responses of teachers in the Surfcoast cluster, shown in Figure 11. There appears to have been a strong positive shift in mathematics particularly, reflecting the primary focus on mathematics in the cluster.

Figure 11: Coordinator ratings of changes in team processes in Surfcoast cluster



The impact of IMYMS

From the analysis of cluster reports and activity above, it is clear that there were many worthwhile initiatives as a result of IMYMS and considerable change in some schools and clusters. As would be expected, however, there was variation both across and within clusters and schools, concerning the degree of innovation and the degree of improvement in mathematics and science provision. There was acknowledgement in the final network meeting discussions that the outcomes of IMYMS are variable across teachers:

> *What will be left behind when we've done out couple of years. Will I be a better science teacher. Will I be a better maths teacher. Will I be able to communicate those learnings more ably to my colleagues. And I suppose … simply as a observation the way that individual teachers in the cluster answer those questions will be very much dependent on them. They'll be quite variable the answers to those questions that we'd expect.*

> *Look the outcomes or the changes being far more successful with some teachers than others, I won't deny that. However being in a position to say well you need to do this, is really handy, and so I had to say that on occasions. But in general I think teachers got into the spirit of the project and in general through our college I think there'll be some good and enduring legacies.*

Some of this variation, and the reasons for it, will be discussed in the section below on the change process, and some insight into the nature of and extent of improvement at the school level comes from data collected at the final network meeting. For an overview of judgments concerning the impact of IMYMS, however, we can turn to questionnaire data.

On the final questionnaire, cluster coordinators, school coordinators and teachers were asked to nominate the degree of different IMYMS had made to teachers' motivation and practice. The return rate for this questionnaire was low, for school coordinators from some clusters. Some respondents ticked two boxes, particularly the cluster educators who presumably were reflecting variety in the schools in the cluster. Table 16 shows that IMYMS resulted in substantial change in many schools, but partial success in reaching all teachers in other schools. Particularly for secondary schools, it was difficult to get all staff engaged in the project, depending on local circumstances.

Table 16: Impact of IMYMS, from final 2005 questionnaire

Impact of IMYMS	Cluster educators	Primary IMYMS coordinators	Secondary IMYMS coordinators	Teachers
IMYMS has resulted in middle years staff generally reflecting on their mathematics and science teaching	2	7	1	25
IMYMS has resulted in some motivated middle years staff working together to improve their mathematics and science teaching	3	8	3	26
IMYMS has not made a lot of difference to mathematics or science teaching in our cluster	-	1	-	2

From the final questionnaire, the cluster educators were very positive about the commitment and effective working relationships with the IMYMS teams in their clusters, and their success in generating enthusiasm. Understandably, the Ocean cluster educator, who had come into the project late and was at that stage dealing with a cluster in which almost all the IMYMS coordinators had left their schools or been given other responsibilities, rated the commitment and enthusiasm much lower.

The change process

In this section we will trace the change process through interviews with cluster educators and coordinators, and through transcripts of the discussion at the final network meeting. The sense of ownership of the initiatives and the flexibility for clusters to focus on agendas important to them, is illustrated by the following comments made at the network meeting:

> *I think it the thing that which has made a big difference as a change process for us is the fact that the focus for the cluster have come bottom up. Its come from teachers. Its come from the data through the component mapping or through the kids surveys or whatever else … And I certainly think that that gave us a real good focus and ownership thing right from the beginning*
>
> *And I've certainly noticed after the last two years increasingly staff and more happy to go through this process of saying, okay we've got an issue here, we'll work on it and so be it. There's nothing other than that. So I think this reflection stuff…had been important to us*
>
> *Cluster educator, network meeting*

The strategy allowed ownership of the change process but also provided focus, which it was claimed other clusters lacked:

> *I think one of the most positive aspects was that it gave the cluster a specific focus and in a lot of clusters you didn't have like a research component already in place. …the people in my capacity I've spoken to they were floundering a lot because they didn't have certain directions so I think that was probably the most important aspect.*
>
> Cluster Educator, interview

Clusters and schools as the locus of innovation

The School Innovation model was first developed in SIS with individual schools as the unit of change, each school developing their action plan but meeting in regional groupings to discuss the process of change. With PoLT, and now with IMYMS, more emphasis is placed on the cluster. There was an ongoing tension, often positive, between innovation and leadership in schools, and innovation at the cluster level.

> *We spent 6 months almost just trying to market the cluster concept. You know interaction between schools. What is the cluster. What's its purpose. How's it fitting the rest of the stage. You know getting teachers aware that every school is involved with a cluster.*
>
> *T Primary School has always viewed itself as fairly independent and a provider of things to other schools .. And I think its given access to smaller schools like O Primary who have seen their numbers fall .. in the last 3 or 4 years - access to professional sharing of knowledge with other schools close by who are more fortunate with their enrolment. Its definitely improved interaction and the sharing of resources between schools, without a doubt.*
>
> *I think that schools are more focused on their own specific setting. Their own specific agendas. So they'll always place more emphasis on that and put the cluster secondary. So they see value in like that affiliation, 2 or 3 schools in a cluster but when it comes to an action plan they'd be looking more in terms of their own individual unique setting.*
>
> Cluster educator interview

Contextual factors in the change process

The prior history of schools in the cluster was a significant factor influencing the progress of the project. For instance, in all the clusters there were schools that had been involved in SIS, and this affected their acceptance of the strategic planning process, including the component mapping, an their willingness to plan as a team. Another factor was the prior history of relationships between schools:

We're a but lucky I suppose in Hume cluster because the last 5 years we worked very closely with our primary schools to develop quite a few units together. We've had our third learning fest in the last 5 years which has been very successful so there's one bit of tradition having started off I suppose in the 5 years we've had to develop those contacts with our primary schools. So that's been a bit of an advantage for us because it means that those connections there we've been able to really work with developing things in the programs and going ahead in leaps and bounds.

Cluster Educator, network meeting

An important focus of IMYMS was the school team as the driver of change, and this was evident in the charts on team processes described above (Figures 9 ad 10) and also in discussion at the final network meeting.

Another that has worked well, … we have for a few years worked in small teams of teachers so for example my year 7 team, I teach maths and science. Other teachers SOSE and English maybe so the kids have only got 4 or 5 main teachers instead of the usual 11 or so. So we're reducing the amount of teachers to kids. Have the integration process and that's evolved over about 3 or 4 years or working in the primary schools. Going out. We did a lot of work with shadowing. Primary school teachers they came up with us so we have good involvement with our primary schools in developing fairly good curriculum I think. We're just looking now in continuing the process. We're doing SIT now so we're doing the SIT process but we're looking at doing POLT right across the school anyway.

IMYMS coordinator, Hume SC

This quote also indicates the range of projects some of these clusters and schools were involved with. The fact that these clusters were involved in other Innovation and Excellence initiatives is discussed above, and this was clear from the discussion in the network meeting and interviews, where change to school culture was described as being due to a range of interconnected projects and factors such that it was difficult to single out specific effects at this level as being due to IMYMS.

Complexities in the operation of IMYMS were experienced in a number of schools and clusters who were committed to a number of other programs. In some cases schools were engaged in MYPRAD, or in other innovation and excellence initiatives. This meant that cluster coordinators had to divide their time and resources, and school coordinators had to compete with other curriculum areas for attention and resources. This happened despite the initial agreement that IMYMS would become the major focus for participating clusters. However, the discussion at the network meeting, and interviews, demonstrated the synergistic effects in some cases on interlocking initiatives.

Competing prior agendas

In many cases, differences in school coordinators' commitment to the project determined the way IMYMS was perceived as fitting in with, or interfering with, already existing directions and agenda. For example, one secondary school was undergoing a curriculum restructure and were committed to developing a new Year 11 program, so that this took attention and energy away from IMYMS. Had the project been started a year earlier, it may have been able to be used more strategically to help set a direction for the new program. As it was, the direction was to a large extent set, and IMYMS sat somewhat on the periphery in this process. In other cases, projects that were already under way were a positive aspect of the school's work. One secondary school was already making moves to integrate Year 7 and 8 mathematics and science, and the science department was developing assessment processes that allowed for individual pathways through science with streaming. These initiatives aligned well with IMYMS, largely due to the energy of the coordinator. Another secondary school was already implementing some interesting approaches to incorporating problem solving in the mathematics curriculum, and IMYMS provided a framework for further development of this initiative. A third secondary school underwent a curriculum change, with changes to timetabling, and the science department committed to compiling resources and activities as an online database. In that case there was some difficulty with the coordinator being committed to introducing an activity focused science and mathematics curriculum that would engage students, and the unproblematic view of pedagogy that was associated with this cut across the IMYMS pedagogy focus.

These types of issues are characteristic of busy and often over committed schools who are balancing multiple projects. An important lesson for change projects like IMYMS is the need to ensure that everyone involved in the project, at various levels, is 'on board' and committed to the process. In some of the IMYMS schools this was initially more true of principals than staff, and for a few schools remained the case.

Rural and regional issues

Three of the four IMYMS clusters were rural or regional, with the Ocean cluster being particularly distant from Melbourne, where the network meetings were held. In this particular cluster, distance and communication was particularly difficult due to the distance between the Ocean and Swifts Creek areas, and the number of small primary schools spread across wide distances. This meant that the cluster was committed to spending a considerable part of its funding on a car for the cluster educator, and that it was hard to get all school coordinators together. Although a number of visits occurred, it was very difficult for the IMYMS team to visit, and extra resources were required to support teachers from this cluster for the network meetings. The cluster had a number of challenges associated with geographical isolation. In Swifts Creek secondary college there are a number of staff who share teaching, and work part time. This made it hard to call planning meetings, and also made it difficult to find replacement teachers to support team meetings. In a number of the smaller 1-2 teacher schools, despite the best of intentions, joint planning meetings and visits were difficult to achieve.

The IMYMS strategy

Aspects of the IMYMS strategy were generally well received by cluster educators in their questionnaire responses. The importance of the team planning and leadership, and the extent of change in team processes has been discussed above.

Component mapping

At the final network meeting there was quite a long discussion about component mapping as a worthwhile tool. Many of the comments mirrored those that had been found for SIS concerning the opportunity for significant discussion of pedagogy, the professional learning and reflection that resulted, and the impetus it provided for change.

> *We found that the component mapping process actually increased the discussion of how to arrange improved teaching and learning across the cluster or in our individual teams. It also allowed us to focus on a particular components to deal with so the people aren't working on things in isolation. One of the biggest advantages I suppose with doing the whole process was that we're actually working in teams for common goals for our action planning. What we found worked really well.*

> *… everybody was quite willing to do the component mapping. Some of the older staff were a little bit worried that it was going to show up that they were failures as teachers and they were really nervous about the whole process. But what I did with the data was to do graphs and stuff when we had PD time out of school down at a café …and we just went through all the data and we looked at all the things. You know we did well. And we had a look at a couple of things. So it was a cause for celebration and no it doesn't look gloomy. So it reassured everybody.*

> *I can remember a teacher…can't think of his name, but the PoLT PD that we went to earlier this year, he said in 35 years no one ever really sat down with me and said what are the best things about your teaching. And why do you do it and how do you enjoy it and that sort of thing. And he said POLT component mapping he said is fantastic cause I can sit there for an hour, I get an audience that's tuned in on me, and I get to share, and it's a wonderful thing. And we found it was a good positive experience for the staff and I think that it was great having G* come on board in that he was relatively new to the school so there wasn't a history there. It was probably an*

opportunity for G to get to know staff and an opportunity to just sit down and talk one on one, and I think it was really important in terms of having G* there that he has a great relationship with the people he works with so there's a lot of trust and the ability to confide in G**

Can I just say for some of us who have been in the system a very long time, I've been brought up in a certain way and taught a certain way, it was quite confronting and I know and also through … some PLTs this year…for the last 21 years …I suppose my attitude has changed a bit. So kids say oh what are you teaching. I'm not teaching. I'm helping you to learn. So the component mapping has actually made me look at the way that I work … made you look at yourself very closely. And perhaps some of us are to generous to ourselves and others are very hard on ourselves but if it made you look at the way you do your job and step out of the comfort zone, its very worthwhile.

There was staff at the school that had done it so they had some experience. And I think one of the things about the component mapping, and it does take a lot of time, but as teachers you don't often get that time to sit and refect professionally and it gives you a structure for doing that.

A variety of comments at the network meeting, and from IMYMS coordinator interviews

There were, however, problems raised of time with the Component mapping in big schools especially, and with schools and teachers who had previously been involved in SIS and PoLT, both of which involved Component mapping, and with the value for schools in component mapping at the end of the project when it has a summative rather than formative purpose:

I think my concern is at what stage does component mapping maybe lose its impact. If you're got a group of teachers might have component mapped in science in schools and again in IMYMS, and now again in POLT, there will be a stage where it will lose impact and I think that's something one needs to bear in mind.

Cluster educator, interview

When it came to sort of IMYMS came along we were a little bit … …like yes we've done component mapping, cool lets do component mapping again, but as you mentioned but with slightly different terminology and developing that terminology certainly wouldn't happen at our school. People are like … whatever … Anyway we did a bit more component mapping and then we've done more recent component mapping. And that just in itself is problematic. Just the number of hours required to get component mapping done. Because you've only got so many hours in the day and so if you spend 40 hours component mapping well that's on top of teaching and …all the stuff, teacher stuff. So that's the problematic aspect of IMYMS.

When I think about IMYMS rather than just the stuff that's been happening at our school I say to myself I think of component mapping which is … a fantastic thing, but does the amount of time put in to component mapping every single staff previously, then at the beginning of the year, then just recently, match up with its powers as a tool to initiate and motivate change. I would say not. I'd say it certainly has… as an initial thing … but then to come back and component map again, I would say I don't see a lot of value in that. But certainly gave us the ideas. Look at these areas we need to work on.

IMYMS coordinator, large secondary school

Some schools had been involved in SIS and were much further advanced than others in science planning. This was in some cases a positive influence, but in at least one case there was some feeling at the school that they had "done" science before, and the component mapping was hard to organise and justify for this reason.

Student surveys

Some teachers felt that the student surveys did not provide useful data since there was a tendency for them to become 'popularity polls' of teachers and others claimed that students had not taken them seriously. However, there were some very positive comments from teachers and schools who had used the information productively:

We had really, really good…that school survey data that came back in this year was fantastic and all of the staff have just been having such a rich mix of ideas.

Just one little change we're noticing at our school is when we got the data from the attitude surveys, last year it wasn't so good, and then there've been a lot of changes in the 5, 6, team and some hassles and issues with staff, so I mean…and teachers are already talking about you know the surveys for next year and what we're going to do about…you know what we put in place hoping that that will improve. And I think just having staff talk about those sorts of things is a natural part of what they're doing now. Has actually happened quite quickly.

Can I go back 5 years … we talked teachers, we usually converted it to content, you very rarely ever talked pedagogy, and we didn't ask the kids anything. And I think 5 years down the track we now acknowledge that kids have opinions of the sessions which are important to our teaching and that we need as teachers to consider where our pedagogical stance is in response to those needs. in that 5 years I've seen more change (in) beliefs and understandings than in the previous 35 years. I think just the perspective of where we are should never be taken for granted but that's actually been … a monumental shift in a very short space of time.

Leading change

The quotes above demonstrate the nature of the task that cluster educators had in bringing schools on board a coherent agenda. This is a leadership issue, and involved working through principals, and IMYMS school coordinators.

I think the success of any sort of these projects is largely dependent on those people, the coordinators, cause they are the people who in essence are actually implementing the program at the school level. My role is for the facilitator or manager. Its their role though to actually get things going in the school and get on with the job. So I think we've been lucky. We've had very active enthusiastically committed coordinators.

I think another issue is, is to make sure that you've got very shared vision, common goals, amongst the management team. Its very easy for different principals to have either separate agendas and that was an issue at the beginning of the whole cluster concept and its only recently that there's been more of that…certain common goal that you've been working towards.

Cluster educator interview

Cluster educators had to deal with a variety of responses to and levels of commitment to the change process, often with visible negativity:

To a large extent in the secondary school there were certain personalities there that just don't like facing any new initiatives of taking on anything that might put them out of their normal comfort zone.

It's a difficult situation because X had a very distinct sort of culture that's developed over the years and tried to make wholesale changes the last 3 or 4 years and you know R the principal, has been very progressive in his thinking and his attitude, and his actions, some teachers haven't necessarily agreed with his vision.

I think it's a combination of political and logistical. In a staff that big with very rigid time table as opposed to a [small] primary school …it was an issue just to find the time and release teachers, and give them the opportunity to even sit and do component mapping or to conduct a survey in the class. You know the teacher might be just getting on a bit. Easy units of work or *whatever, so a range of issues. But I think the biggest problem was the size of the school. The number of staff … even though I've been working in that school now for a number of years, I walk down a corridor and … obviously the faces have been there for a while, you recognise, but there are just so many teachers that its very difficult to actually build any personal relationship with any of them.*

The relationships between primary and secondary schools were in some clusters, if not all, somewhat coloured by the different cultures that exist in the two systems with regard to views of learning, commitments to students and subjects, and different organizational structures.

The biggest issue has been the distinct difference in culture between secondary school teaches and primary school teachers. That's the biggest issue facing most plus educators I think. That you're working within two very different cultures.

Primary school teachers in general are prepared to take on new initiatives and embrace change and all the rest of it, much easier than secondary school teachers. Secondary school teachers are very, very KLA specific and generally view their primary school colleagues as being lesser human beings almost because their generic teachers that don't have any sort of academic standing or whatever. So there's that whole culture that exists that is going to take years and years to change and then who knows if it ever will change. So that has been the biggest issue.

So to get secondary teachers on board and then to recognise that it actually is of worth to be involved in these sorts of projects, or in a cluster itself, that they can actually benefit from primary schools. You know a lot of them view that primary schools can benefit from them, but they can't really benefit from having any relationship with primary schools. So that has been biggest issue and the biggest challenge.

In secondary schools … because I've been teaching the primary school, I was reviewed as maybe not… [kosher] … and liKewise other cluster educators who've come from the secondary school background haven't been well received in primary schools so its taken a bit of time to try and just establish one's credibility or credentials in the secondary school environment.

Cluster educator interview

Effect of IMYMS

During IMYMS there was substantial evidence of productive change in the stories of the innovations that schools and clusters instituted, in the questionnaire data, and from presentations, observation and discussion at the cluster and network meetings. At the final network meeting, many of the comments confirmed that IMYMS had led to significant changes:

You asked the question about has it been…well how have the clusters worked. I think that certainly this has given us the forum for having dialog. Like if Surfcoast Secondary just edit the last 2 days and the occasions that we've been away as a group, its just giving you that opportunity which you may not be given normally daily life at school to actually just sit down with the other teachers and converse and I think there's lot of benefit there for sharing ideas and practices. And what issues are and concerns and those sorts of things as well.

.. we've had huge changes at Surfcoast in the last 4 years and I'd say yes to all of your questions of have we had changes. Are the kids getting their outcomes and so forth.

We're getting feedback in terms of increased enrolments in science and mathematics. As soon as it becomes an elective in year 9 we get more and more kids choosing into those subjects. Physics, chemistry and otherwise, biology, psychology.

In some areas its not happening as well, as some areas, the mathematics area, the changes are not as dramatic as they are perhaps in science and there's a whole range of reasons for that. Is *that all due to IMYMS, well obviously not. That's never promised to be a magic wand that was going to do all of that. And yes are we finished that progress, no we're not. And we're still going along. We're still making changes.*

Comments from various Surfcoast cluster staff at the network meeting

In response to a discussion on how much change IMYMS has led to:

I've sat here for 2 days and heard 3 people from my cluster talk about initiatives that they've been through and in terms of those particular components there's been a monumental reform in achieving those. i.e. component mapping and science. So on that basis alone if that continues and extends across further components then I think the case rests.

Network participant comment

And from a cluster educator:

Kids tend to be sort of enjoying those (mathematics and science) subjects more than what they used to in the past. You've got people like R now experimenting with different things in biology and science and that so (the coordinator) has really been encouraging the change in the traditional teaching styles, and the old technocratic approaches, and talking, and all the rest of it. And using a lot more younger teachers there's more enthusiasm so I think that's rubbing off on all the students.

I mean I couldn't say specifically this, that and the other, but just the whole general culture seems to be changing. General attitude seems to be changing. And a more positive vibe amongst the teachers.

IMYMS has been one of these things that's brought about change, but … it is one of many.

Conclusions and implications

This report shows that, as a professional learning initiative within the Innovation and Excellence framework, IMYMS resulted in a variety of worthwhile initiatives, and substantial change in school and teacher practices in many schools and most clusters. As a research study, IMYMS achieved substantial insights into the issues surrounding middle years mathematics and science teaching and learning, and ways of improving these. These insights are discussed below under the research questions driving the study.

Q1 What are the specific characteristics of science and mathematics knowledge and learning that require differences in the formulation of effective teaching and learning?

The question of the specific characteristics of mathematics and science was answered through a number of aspects of the study. The interviews with effective teachers of mathematics and the subsequent development of the IMYMS Components exposed differences in the perceptions and practices of teachers in these subjects. In mathematics there is a greater concern with conceptual practices that build over time. This implies greater attention to sequencing and mastery of specific content, the need for individual support for students – particularly those at risk – and the setting of specific and high standards that will allow students to master content needed in subsequent years. In science there is greater focus on the context of science ideas as the key to meaningful learning, on the representation of the many ways science is relevant to students' lives and used in the community, and on the use of practical activities. In both subjects, problem solving and investigation were seen as central, but were viewed in different ways.

These differences were also apparent in the teacher component mapping data where a number of significant patterns emerged, as well as in the student perceptions data where there were substantial differences in the patterns of student enjoyment of the two subjects, and perceptions of the usefulness of the knowledge. In essence, and particularly in primary school, mathematics was seen as useful and important while science was seen as more enjoyable. The student learning preferences data also showed up differences consistent with these findings.

The implication of these differences is that the subjects have distinct ways in which progression of knowledge is envisaged, in terms of curriculum organization, pedagogy, assessment, and student support, and that the training of teachers in these subjects must incorporate these substantial cultural differences. There are substantial limitations to generic notions of effective middle years pedagogy.

Q2 How can effective pedagogies in mathematics and science be monitored reliably?

As with the School Innovation in Science (SIS) research project, the component mapping process was held to be a substantial professional learning activity, providing insights into individual teachers' practice (for both the teacher and coordinator) and a platform to plan for improvement. Video data was collected of a small group of teachers as part of the exploration of research question 4, and these provided a rich resource for discussion of pedagogy. It became quickly clear, however, how complex and contextual these videotapes were as representing the overall practice of individual teachers, and the on-the-ground verification of component mapping data with these small snapshots would be unreliable. Component mapping remains a powerful means of supporting and monitoring classroom pedagogy.

Q3 How can students' conceptual understandings in mathematics and science and ability to work mathematically and scientifically be assessed reliably?

The project has constructed a variety of instruments for assessing students' mathematical and scientific capabilities. The written tests were constructed around curriculum outcomes matched to the particular programs in schools, and contained items focusing on conceptual understandings and practices, reasoning, and thinking mathematically and scientifically. The student survey provided a measure of student disposition. The performance tests assessed problem solving and investigative knowledge and skills, and reasoning.

The tests demonstrated substantial growth in student understanding over the year. The further analysis of these aspects of student capability in mathematics and in science, and between these subjects, is ongoing as part of Christine Kakkinen's PhD studies. The project has, using this student capability model, developed an approach to assessment of students' work in science and mathematics that has wider implications for assessment policy.

Q4 What are the links between teachers' pedagogies in mathematics and science?

Linda Darby's study has extended the insights relating to question 1 to look closely at teachers' pedagogies in science and mathematics. That study has shown substantial differences in the ways in which teachers perceive the conceptual organization of the curriculum, the role of activities, the way relevance is perceived in the two subjects, and the importance of aesthetics dimensions of teachers' response to the subject matter and learning in the subject. This study has substantial implications for the training of teachers of mathematics and science, and for policy and practice relating to teachers teaching mathematics and science 'out of field'. The work highlights the very specific operation of subject cultures in framing teachers' practice, and the need to both represent, and critically respond to this in teacher training and professional development.

Q5 How do the cultures of teaching and learning of mathematics and science in primary and secondary schools affect the way change is constructed and pursued?

The changes in school and teacher practice in IMYMS, while substantial, are not as compelling as with the SIS project. This reflects the more limited resources that went into professional development support, the shorter time scale, in some cases the lack of continuity of leadership within the project, and the fact that clusters were focusing on a range of projects alongside IMYMS. The patterns of planning and change were similar to SIS, in terms of the operation of the action planning and building of momentum in teams, but in some ways more complex because of the cluster and school interactions. For primary schools, the approach to change differed for mathematics and science because of the different status of the subjects and their representation in the curriculum. For secondary schools the change process was similar, but the focus of the initiatives differed and reflected the relative importance accorded to particular components in the two subjects. Thus, community linked projects were often the focus for science, whereas pedagogies centred around problem solving were common for mathematics. Initiatives such as the development of rubrics for assessment were common to both subjects.

Overall, IMYMS has substantially explored a range of issues concerning teaching and learning in middle years mathematics and science, and the similarities and differences pertaining to these. It has affirmed the critical role of 'subject' in framing policy and practice in middle years pedagogy.

Recommendations for further research and development

Findings from the project suggest two major research directions relating to teacher classroom practice, that flow from IMYMS.

1 ***The development of professional learning based on the IMYMS Components.***
The IMYMS Components have proved to be a robust framework for describing and supporting effective teaching and learning in mathematics and science. Research and development is needed to develop a professional learning approach based on the Components, to help schools and individual teachers improve their practice as measured on this scale. Such a program might well be developed to support the work of school-based coaches in mathematics and science.

2 Support for teachers of mathematics and science teaching out of field
The video based research has shown clearly that the difference in teaching mathematics compared to science relates to much more than conceptual content, and includes a range of perceptions of the subject purposes and organization, and processes for supporting learning and engagement. There are many teachers of mathematics and science who are not trained in these areas, and this research points to major difficulties with this teaching 'out of field'. A research project is needed that uses the findings of this research to develop ways of supporting, through targeted professional learning programs, these 'out of field' teachers of mathematics and science.

Presentations and Publications

Darby, L. (2004). *Affording and constraining the manifestation of pedagogy in middle years mathematics and science teaching.* Paper presented at the annual meeting of the Australasian Science Education Research Association, Armidale, July.

Darby, L. (2004). *Subject cultures and their influence on the pedagogy of two mathematics and science teachers.* Presentation at the DUSA Postgraduate Research Conference, Geelong, October.

Darby, L. (2004). *Subject cultures and their influence on the pedagogy of two mathematics and science teachers.* Presentation at the University of Ballarat Annual Research Conference, Mount Helen, November.

Darby, L. (2004). *The inner and outer teacher: Constructing stories of subject, classroom and identity.* Paper presented at the Contemporary Approaches to Research in Mathematics, Science and Environmental Education Symposium, Burwood, December.

Darby, L. (2005). *Having stories to tell: Negotiating subject boundaries in mathematics and science.* Paper presented at the annual meeting of the Australasian Science Education Research Association, Hamilton, New Zealand, July.

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Tytler, R. (2004). *Science, mathematics, everything: Generic vs. subject specific versions of pedagogy.* Paper presented at the annual meeting of the Australasian Science Education Research Association, Armidale, July.

Tytler, R. (2005). Continuous professional learning through school based strategic planning. Invited keynote address at the International Conference on Science and Mathematics Education, RECSAM, Penang, December.

Tytler, R. (2005). *Supporting teacher professional learning through a School Innovation model.* Paper presented at a symposium 'Quality Learning' at the Universitas Sains Malaysia, Penang, May.

Tytler, R. (2005). *Teacher quality development through a School Innovation model.* Paper delivered to a symposium on quality learning, Taiwan Normal University, Taipei, December.

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Tytler, R. (2004). Science, mathematics, everything: Generic vs. subject specific versions of pedagogy. Paper presented at the annual meeting of the Australasian Science Education Research Association, Armidale, July.

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Tytler, R., Smith, R., Grover, P., & Brown, S. (1999). A comparison of professional development models for teachers of primary mathematics and science. Asia Pacific Journal of Teacher Education, 27(3), 193-214.

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Appendices

Appendix 1: List of Clusters and Schools Involved in the IMYMS Project

Surfcoast Cluster

Surfcoast Secondary College

Seachange Primary School

Brae Primary School

Mt Daniel Primary School

Surfcoast Primary School

Surfcoast South Primary School

Bells Primary School

Parkland Cluster

Parkland High School

Banks Primary School

Halliday Primary School

Parkland East Primary School

Parkland Primary School

Roberts Primary School

Hume Cluster

Hume Secondary College

Hume Primary School

Lesley Primary School

Reilly Primary School

Ocean Cluster

Ocean Secondary College

River Secondary College

Ocean Primary School

Meenyan Primary School

Mona Primary School

Nugent Primary School

Mountain Primary School

St Bede's Primary School

Pelican Primary School

River Primary School

Timber Primary School

Thomas' Arm Primary School

Appendix 2: Timeline and project summary

Year	Term	Activity
2003	4	• Interviews with effective teachers of mathematics • Identify participating schools & negotiate involvement • Recruit & enrol APAIs
2004	1	• SIS Components extended to mathematics • Construction and trial of component mapping instrument • Draft Mathematics & Science Leading Change PD • Coordinators & Cluster Educators attend Leading Change Network Meeting 1, which include training in working as researchers in the school, taking field notes, interviewing & working as change agents • First component mapping of teachers • Visits to clusters
2004	2	• Administer first student perceptions and learning preferences survey (all year levels 5-9) • Continue regular visits to clusters
2004	3	• Begin to develop written tests of knowledge & understanding in mathematics & science • Continue regular visits to clusters
	4	• Administer questionnaires probing different layers of school change • Plan performance testing • Begin videotaping lessons for selected teachers • Continue regular visits to clusters
2005	1	• Network Meeting 2 for schools to share ideas and successes from 2004 and to train teachers in performance testing • Support schools to redevelop action plans • Component mapping of new staff • Continue videotaping lessons for selected teachers • Administer first written test of Knowledge & Understanding (mathematics & science, all students, year levels 6 and 8) • Continue regular visits to clusters • Write papers for publication based on preliminary analyses
2005	2	• Administer second student perceptions and learning preferences survey (all year levels 5-9) • Continue videotaping lessons for selected teachers • Continue regular visits to clusters
2005	3	• Administer performance test for assessing mathematics and science skills • Continue videotaping lessons for selected teachers
2005	4	• Administer second written test of Knowledge & Understanding (mathematics & science, all students, year levels 6 and 8) • End of year interviews with some coordinators and students • Teacher and coordinator questionnaires and submission of school reports • Second component mapping of all teachers • Third and final Network Meeting for coordinators & cluster educators
2006		• Report back selected findings to clusters • Conduct some interviews with coordinators and selected teachers • Continue to analyse data • Develop case studies of clusters and schools and change • Conduct further interviews of students concerning perceptions • Write interim report for DE&T & participating schools
2007/8		• Refine and systematise the large data sets of test results • Conduct analyses concerning change in student scores • Analyse change processes in clusters and schools • Present findings in Australian and international conferences

	• The two APAIs continue to analyse data and write their PhDs • Develop final report

Appendix 3: The IMYMS Components of Effective Teaching and Learning

1. The learning environment promotes a culture of value and respect

1.1 The teacher builds positive relationships through knowing and valuing each student

1.2 The learning environment is characterised by a sense of common purpose and collaborative inquiry

1.3 The learning environment provides a safe place for students to take risks with their learning

1.4 Persistence and effort are valued and lead to a sense of accomplishment

2. Students are encouraged to be independent and self motivated learners

2.1 Students are encouraged and supported to take responsibility for their learning

2.2 Students are encouraged to reflect on their learning

3. Students are challenged to extend their understandings

3.1 Subject matter is conceptually complex and intriguing, but accessible

3.2 Tasks challenge students to explore, question and reflect on key ideas

3.3 The teacher clearly signals high expectations for each student

4. Students are supported to develop meaningful understandings

4.1 Teaching strategies explore and build on students' current understandings

4.2 Individual students' learning needs are monitored and addressed

4.3 Students are supported to make connections between key ideas

4.4 Teaching sequences promote sustained learning that builds over time

4.5 Learning sequences involve an interweaving of the concrete and the abstract/conceptual

5. Students are encouraged to see themselves as mathematical and scientific thinkers

5.1 Students are explicitly supported to engage with the processes of investigation and problem solving

5.2 Students engage in mathematical/scientific reasoning and argumentation

6. Mathematics and Science content is linked with students' lives and interests

7. Assessment is an integral part of teaching and learning

7.1 Learners receive feedback to support further learning

7.2 Assessment practices reflect all aspects of the learning program

7.3 Assessment criteria are made explicit

8. Learning connects strongly with communities and practice beyond the classroom

8.1 The learning program provides opportunities to connect with local and broader communities

8.2 Learners engage with a rich, contemporary view of mathematics and science knowledge and practice

9. Learning technologies are used to enhance student learning

Appendix 4: Student Perceptions Mathematics Items Grouped by Component

1. The learning environment promotes a culture of value and respect

1 It is OK to say what I think in my maths class

13 We are encouraged to respect each other's ideas in my maths class

25 My teacher values my work and ideas in maths

2. Students are encouraged to be independent and self motivated learners

2 In my maths class I am expected to make decisions about how I do my work

14 My teacher expects me to think about how well I understand things

26 In my maths class we are encouraged to work things out for ourselves

3. Students are challenged to extend their understandings

3 The maths we do in class makes me think and ask questions

15 My teacher expects everyone to do their best in maths

27 Sometimes the activities we do in maths are hard but they help us learn

4. Students are supported to develop meaningful understandings

4 My teacher tries to find out what I know when teaching something new in maths

16 My teacher uses activities that help me understand new ideas

28 My teacher tries to help everyone understand maths

5. Students are encouraged to see themselves as mathematical and scientific thinkers

5 I am expected to explain my thinking in maths

17 In my maths class we do lots of investigations and problem solving

29 In my maths class we often talk about our ideas

6. Mathematics and Science content is linked with students' lives and interests

6 In maths we study things that interest me

18 The maths we do is often connected to things I am interested in outside school

30 My teacher tries to make maths interesting for everyone

7. Assessment is an integral part of teaching and learning

7 My teacher's comments on my maths work help me learn better

19 My teacher always tells us how our maths will be marked

31 My teacher gives me helpful feedback about my maths

8. Learning connects strongly with communities and practice beyond the classroom

8 In my maths class we work on projects outside school or have people come to talk to us

20 We learn about ways that maths is used in everyday life

32 In my maths class we look at things in the news or work on problems that affect our lives

9. Learning technologies are used to enhance student learning

9 We use technology to explore new maths ideas

21 We use technology to solve maths problems

33 In maths we can use technology to help with our work

10. Enjoyment of mathematics[1]

10 I enjoy the work I do in my maths classes

22 Learning maths at my school is fun

34 I enjoy learning maths at my school

11. Aspirations to achieve in mathematics

11 I really want to learn about maths at school

23 I really want to do well in maths

35 I like to try hard with my maths work

12. The value of mathematics to future success

12 What I learn in maths will be useful to me when I leave school

24 What I learn in maths will help me in the future

36 What I learn in maths helps me in everyday life

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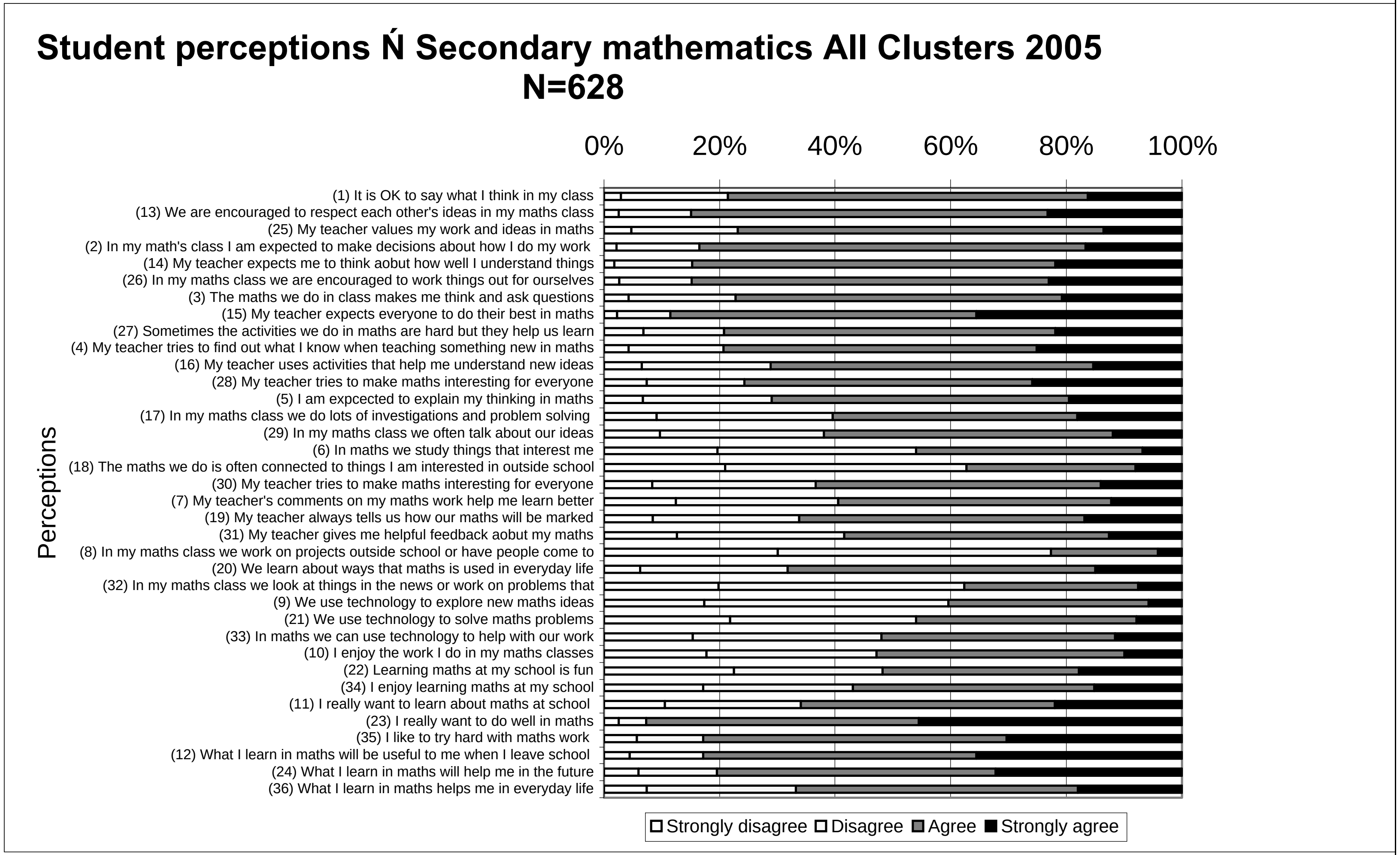
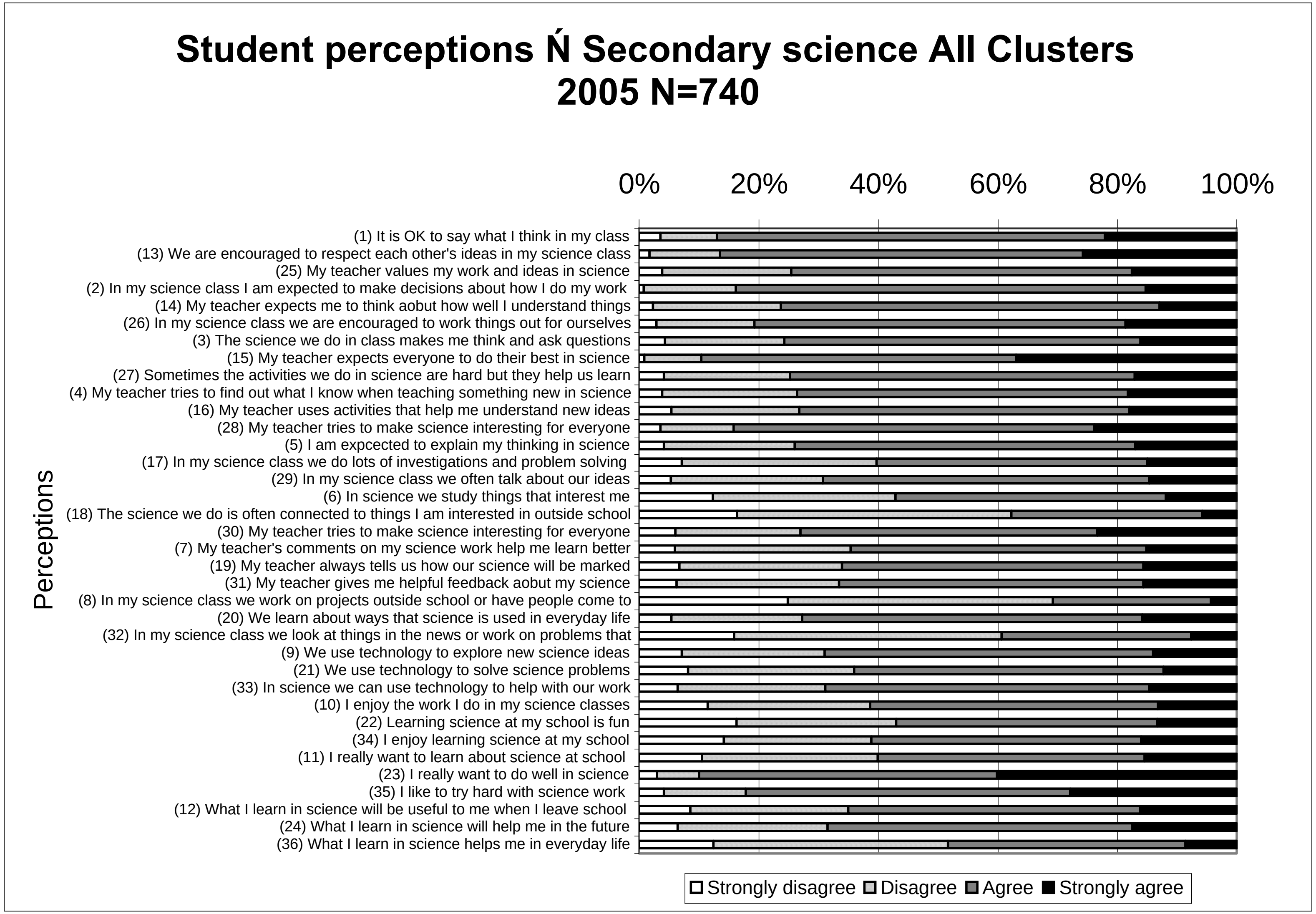
1 Headings 10, 11 and 12 refer to the attitude questions and are not linked to components from the IMYMS Components of Effective Teaching and Learning.

Appendix 5: Student Mathematics Learning Preferences Items

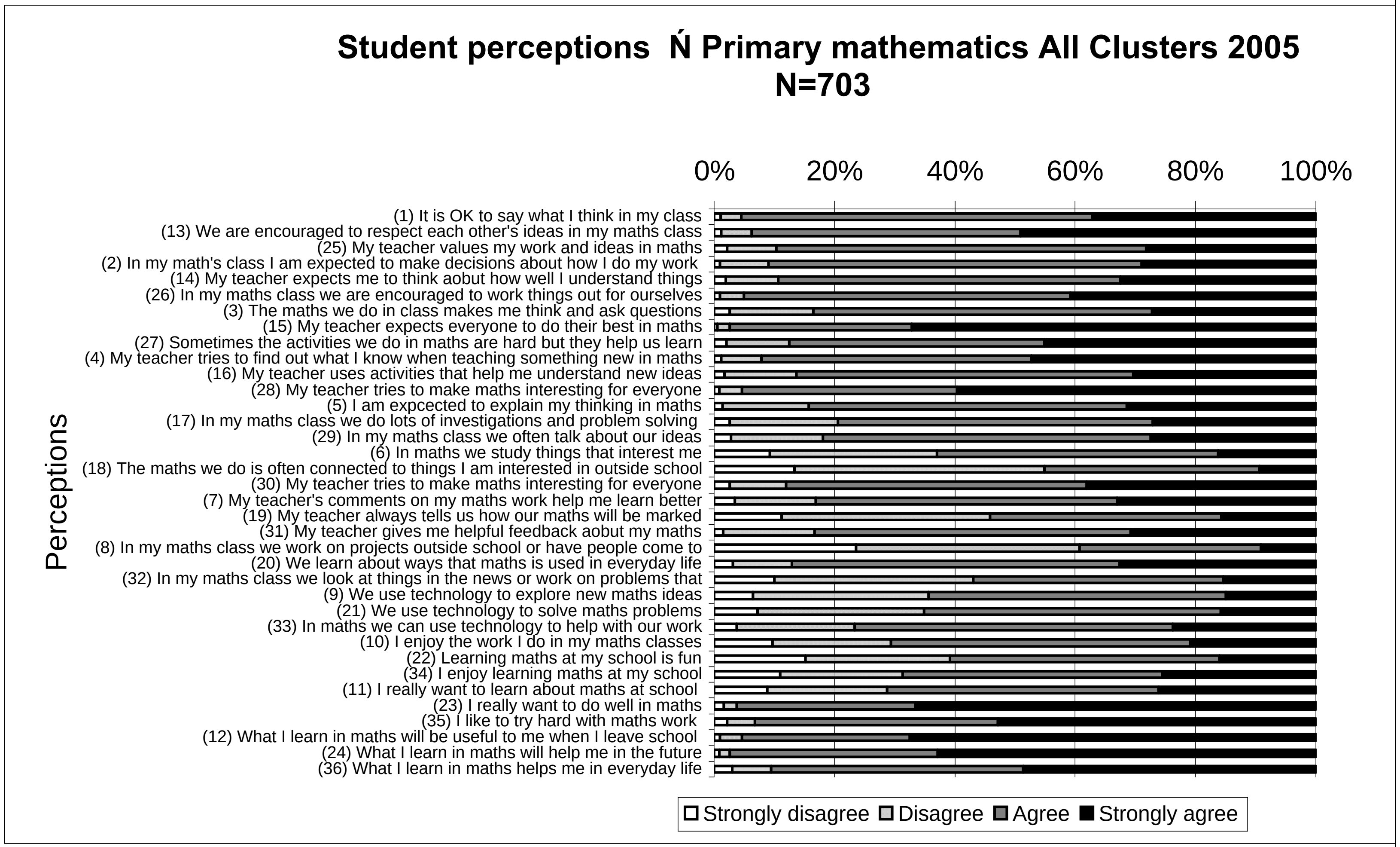
1. Taking part in class discussions
2. Doing exercises or answering questions from a book
3. Doing hands-on activities
4. Doing homework
5. Working in small groups
6. Doing worksheets
7. Listening to the teacher explain ideas
8. Playing games
9. Doing investigations or projects of my own choice
10. Using computers or calculators
11. Watching the teacher show us how to do things
12. Going on excursions
13. Copying notes from the board
14. Talking in class about things in the news
15. Asking questions about things that interest me
16. Searching and collecting information using the internet or CD-ROM
17. Doing projects in my local community
18. Giving a talk to the class
19. Listening to a visiting speaker
20. Being able to choose how I present things
21. Watching videos
22. Writing my thoughts about what I've learnt in a diary or journal
23. Doing activities that challenge me to think
24. Searching for information using library books

Appendix 6: Student Perceptions Data

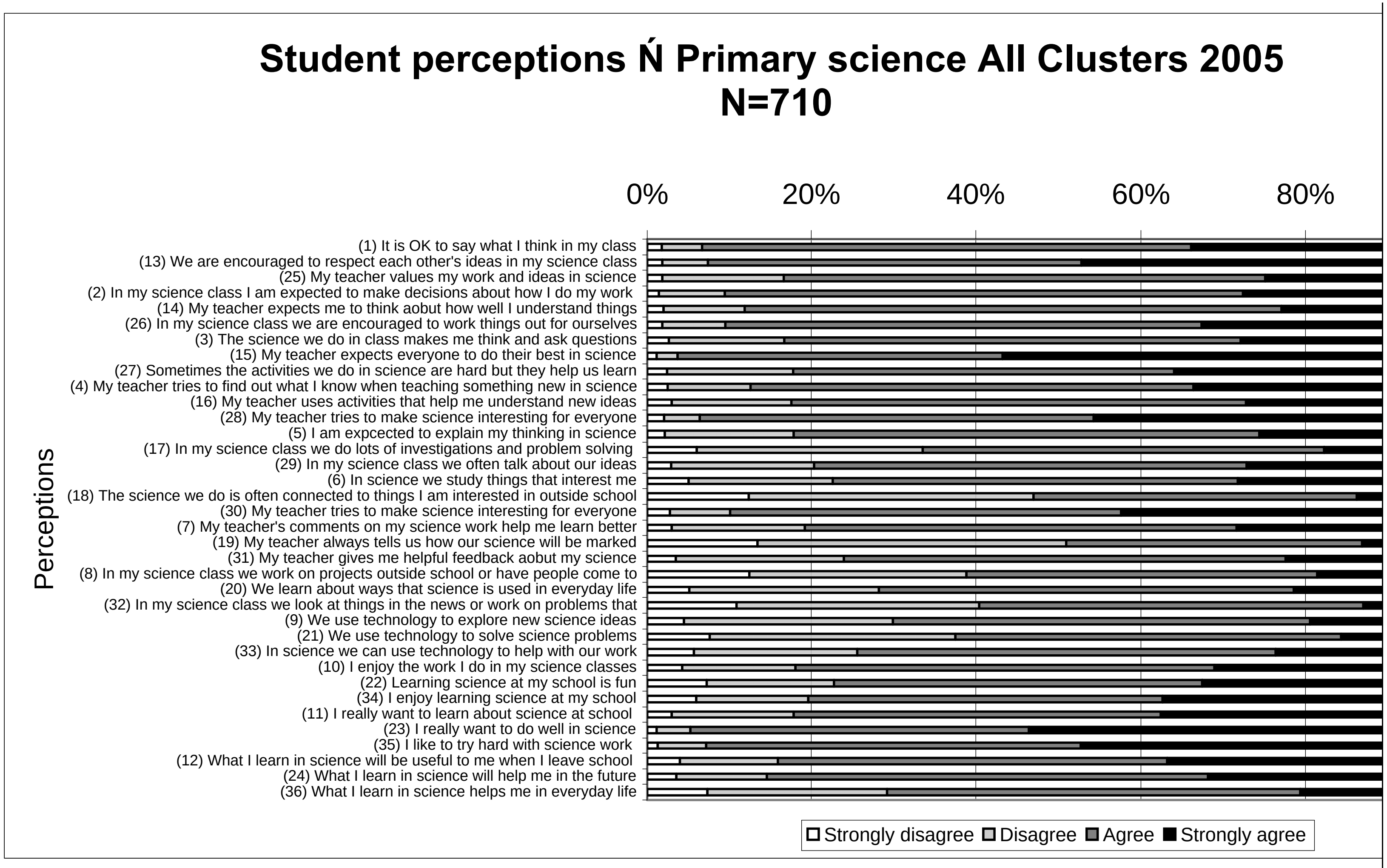




Student perceptions Ń Secondary science All Clusters
2005 N=740
0%
20%
40%
60%
80%
100%
Perceptions
(1) It is OK to say what I think in my class
(13) We are encouraged to respect each other's ideas in my science class
(25) My teacher values my work and ideas in science
(2) In my science class I am expected to make decisions about how I do my work
(14) My teacher expects me to think aobut how well I understand things
(26) In my science class we are encouraged to work things out for ourselves
(3) The science we do in class makes me think and ask questions
(15) My teacher expects everyone to do their best in science
(27) Sometimes the activities we do in science are hard but they help us learn
(4) My teacher tries to find out what I know when teaching something new in science
(16) My teacher uses activities that help me understand new ideas
(28) My teacher tries to make science interesting for everyone
(5) I am expcected to explain my thinking in science
(17) In my science class we do lots of investigations and problem solving
(29) In my science class we often talk about our ideas
(6) In science we study things that interest me
(18) The science we do is often connected to things I am interested in outside school
(30) My teacher tries to make science interesting for everyone
(7) My teacher's comments on my science work help me learn better
(19) My teacher always tells us how our science will be marked
(31) My teacher gives me helpful feedback aobut my science
(8) In my science class we work on projects outside school or have people come to
(20) We learn about ways that science is used in everyday life
(32) In my science class we look at things in the news or work on problems that
(9) We use technology to explore new science ideas
(21) We use technology to solve science problems
(33) In science we can use technology to help with our work
(10) I enjoy the work I do in my science classes
(22) Learning science at my school is fun
(34) I enjoy learning science at my school
(11) I really want to learn about science at school
(23) I really want to do well in science
(35) I like to try hard with science work
(12) What I learn in science will be useful to me when I leave school
(24) What I learn in science will help me in the future
(36) What I learn in science helps me in everyday life
Strongly disagree
Disagree
Agree
Strongly agree



Student perceptions Ń Primary mathematics All Clusters 2005
N=703
0%
20%
40%
60%
80%
100%
Perceptions
(1) It is OK to say what I think in my class
(13) We are encouraged to respect each other's ideas in my maths class
(25) My teacher values my work and ideas in maths
(2) In my math's class I am expected to make decisions about how I do my work
(14) My teacher expects me to think aobut how well I understand things
(26) In my maths class we are encouraged to work things out for ourselves
(3) The maths we do in class makes me think and ask questions
(15) My teacher expects everyone to do their best in maths
(27) Sometimes the activities we do in maths are hard but they help us learn
(4) My teacher tries to find out what I know when teaching something new in maths
(16) My teacher uses activities that help me understand new ideas
(28) My teacher tries to make maths interesting for everyone
(5) I am expcected to explain my thinking in maths
(17) In my maths class we do lots of investigations and problem solving
(29) In my maths class we often talk about our ideas
(6) In maths we study things that interest me
(18) The maths we do is often connected to things I am interested in outside school
(30) My teacher tries to make maths interesting for everyone
(7) My teacher's comments on my maths work help me learn better
(19) My teacher always tells us how our maths will be marked
(31) My teacher gives me helpful feedback aobut my maths
(8) In my maths class we work on projects outside school or have people come to
(20) We learn about ways that maths is used in everyday life
(32) In my maths class we look at things in the news or work on problems that
(9) We use technology to explore new maths ideas
(21) We use technology to solve maths problems
(33) In maths we can use technology to help with our work
(10) I enjoy the work I do in my maths classes
(22) Learning maths at my school is fun
(34) I enjoy learning maths at my school
(11) I really want to learn about maths at school
(23) I really want to do well in maths
(35) I like to try hard with maths work
(12) What I learn in maths will be useful to me when I leave school
(24) What I learn in maths will help me in the future
(36) What I learn in maths helps me in everyday life
Strongly disagree
Disagree
Agree
Strongly agree



Student perceptions Ń Primary science All Clusters 2005
N=710
0%
20%
40%
60%
80%
Perceptions
(1) It is OK to say what I think in my class
(13) We are encouraged to respect each other's ideas in my science class
(25) My teacher values my work and ideas in science
(2) In my science class I am expected to make decisions about how I do my work
(14) My teacher expects me to think aobut how well I understand things
(26) In my science class we are encouraged to work things out for ourselves
(3) The science we do in class makes me think and ask questions
(15) My teacher expects everyone to do their best in science
(27) Sometimes the activities we do in science are hard but they help us learn
(4) My teacher tries to find out what I know when teaching something new in science
(16) My teacher uses activities that help me understand new ideas
(28) My teacher tries to make science interesting for everyone
(5) I am expcected to explain my thinking in science
(17) In my science class we do lots of investigations and problem solving
(29) In my science class we often talk about our ideas
(6) In science we study things that interest me
(18) The science we do is often connected to things I am interested in outside school
(30) My teacher tries to make science interesting for everyone
(7) My teacher's comments on my science work help me learn better
(19) My teacher always tells us how our science will be marked
(31) My teacher gives me helpful feedback aobut my science
(8) In my science class we work on projects outside school or have people come to
(20) We learn about ways that science is used in everyday life
(32) In my science class we look at things in the news or work on problems that
(9) We use technology to explore new science ideas
(21) We use technology to solve science problems
(33) In science we can use technology to help with our work
(10) I enjoy the work I do in my science classes
(22) Learning science at my school is fun
(34) I enjoy learning science at my school
(11) I really want to learn about science at school
(23) I really want to do well in science
(35) I like to try hard with science work
(12) What I learn in science will be useful to me when I leave school
(24) What I learn in science will help me in the future
(36) What I learn in science helps me in everyday life
Strongly disagree
Disagree
Agree
Strongly agree

Appendix 7: Differences in Mathematics and Science Student Perceptions

Secondary Student Perceptions 2005 – Mathematics vs Science

Question	SA[1]	SA + A[2]
12 What I learn in maths/science will be useful to me when I leave school	22.8	17.6***
24 What I learn in maths/science will help me in the future	20.9	14.6***
36 What I learn in maths/science helps me in everyday life	14.3	21.4***
23 I really want to do well in maths/science	9.0	5.2***
17 In my maths/science class we do lots of investigations and problem solving	7.6	14.4***
4 My teacher tries to find out what I know when teaching something new in maths/science	6.8	3.6
5 I am expected to explain my thinking in maths/science	6.1	4.2
35 I like to try hard with my maths/science work	5.1	4.9*
28 My teacher tries to help everyone understand maths/science	4.5	-4.8
3 The maths/science we do in class makes me think and ask questions	4.1	3.2
19 My teacher always tells us how our maths/science will be marked	4.1	1.5
27 Sometimes the activities we do in maths/science are hard but they help us learn	4.1	4.2
15 My teacher expects everyone to do their best in maths/science	4.0	2.6
26 In my maths/science class we are encouraged to work things out for ourselves	3.5	5.8**
14 My teacher expects me to think about how well I understand things	2.1	6.5**
20 We learn about ways that maths/science is used in everyday life	0.7	-1.2
11 I really want to learn about maths/science at school	0.6	1.0
8 In my maths/science class we work on projects outside school or have people come to talk to us	-0.5	-10.2***
13 We are encouraged to respect each other's ideas in my maths/science class	-0.5	-2.3
31 My teacher gives me helpful feedback about my maths/science	-0.7	0.3

7 My teacher’s comments on my maths/science work help me learn better	-1.1	2.5
1 It is OK to say what I think in my maths/science class	-1.6	-8.5***
32 In my maths/science class we look at things in the news or work on problems that affect our lives	-1.7	-8.1**
2 In my maths/science class I am expected to make decisions about how I do my work	-1.8	-2.2
18 The maths/science we do is often connected to things I am interested in outside school	-2.0	-10.8***
33 In maths/science we can use technology (such as computers, calculators or digital cameras) to help with our work	-3.0	-16.9
29 In my maths/science class we often talk about our ideas	-3.8	-9.7
16 My teacher uses activities that help me understand new ideas	-3.9	-5.3*
21 We use technology (such as computers and calculators) to solve maths/science problems	-4.0	-16.0
25 My teacher values my work and ideas in maths/science	-4.8	-1.8
10 I enjoy the work I do in my maths/science classes	-5.6	-11.8***
34 I enjoy learning maths/science at my school	-6.3	-12.7***
6 In maths/science we study things that interest me	-7.1	-15.7***
9 We use technology (such as computers, calculators or digital cameras) to explore new maths/science ideas	-7.4	-30.7***
22 Learning maths/science at my school is fun	-8.0	-18.8***
30 My teacher tries to make maths/science interesting for everyone	-8.3	-9.8***

NOTES

1. SA represents the difference in percentages between mathematics and science students rating each item as Strongly Agree

2. SA + A represents the difference in percentages between mathematics and science students rating each item as Strongly Agree or Agree

* indicates a significant difference at 0.05 level based on a χ^2 test with 1 degree of freedom

** indicates a significant difference at 0.01 level based on a χ^2 test with 1 degree of freedom

*** indicates a significant difference at 0.001 level based on a χ^2 test with 1 degree of freedom

Primary Student Perceptions 2005 – Maths vs Science

Question	SA	SA + A
24 What I learn in maths/science will help me in the future	29.8	11.0***
12 What I learn in maths/science will be useful to me when I leave school	29.6	10.6***
36 What I learn in maths/science helps me in everyday life	26.9	18.7***
28 My teacher tries to help everyone understand maths/science	14.0	2.1
23 I really want to do well in maths/science	12.9	1.4
4 My teacher tries to find out what I know when teaching something new in maths/science	12.7	4.2**
15 My teacher expects everyone to do their best in maths/science	11.0	1.3
20 We learn about ways that maths/science is used in everyday life	10.4	14.1***
17 In my maths/science class we do lots of investigations and problem solving	9.1	12.4***
26 In my maths/science class we are encouraged to work things out for ourselves	8.4	4.7***
14 My teacher expects me to think about how well I understand things	8.3	1.6
31 My teacher gives me helpful feedback about my maths/science	7.6	6.8***
27 Sometimes the activities we do in maths/science are hard but they help us learn	7.1	4.7**
35 I like to try hard with my maths/science work	6.4	-0.1
5 I am expected to explain my thinking in maths/science	5.9	2.1
25 My teacher values my work and ideas in maths/science	4.1	5.9***
7 My teacher’s comments on my maths/science work help me learn better	4.0	2.6
1 It is OK to say what I think in my maths/science class	2.5	1.8
19 My teacher always tells us how our maths/science will be marked	2.4	3.8
13 We are encouraged to respect each other’s ideas in my maths/science class	2.4	1.5
16 My teacher uses activities that help me understand new ideas	2.0	2.9
32 In my maths/science class we look at things in the news or work on problems that affect our lives	0.8	-4.7

2 In my maths/science class I am expected to make decisions about how I do my work	0.5	-1.2
29 In my maths/science class we often talk about our ideas	0.2	1.0
3 The maths/science we do in class makes me think and ask questions	0.0	0.4
21 We use technology (such as computers and calculators) to solve maths/science problems	-0.8	0.6
33 In maths/science we can use technology (such as computers, calculators or digital cameras) to help with our work	-1.3	1.4
18 The maths/science we do is often connected to things I am interested in outside school	-4.0	-7.9**
30 My teacher tries to make maths/science interesting for everyone	-4.6	-1.6
9 We use technology (such as computers, calculators or digital cameras) to explore new maths/science ideas	-5.2	-7.7**
8 In my maths/science class we work on projects outside school or have people come to talk to us	-10.4	-22.6***
10 I enjoy the work I do in my maths/science classes	-11.3	-12.1***
34 I enjoy learning maths/science at my school	-11.5	-12.6***
11 I really want to learn about maths/science at school	-12.0	-11.2***
6 In maths/science we study things that interest me	-12.2	-14.1***
22 Learning maths/science at my school is fun	-16.7	-16.8***

NOTES

1 SA represents the difference in percentages between mathematics and science students rating each item as Strongly Agree

2 SA + A represents the difference in percentages between mathematics and science students rating each item as Strongly Agree or Agree

* indicates a significant difference at 0.05 level based on a χ^2 test with 1 degree of freedom

** indicates a significant difference at 0.01 level based on a χ^2 test with 1 degree of freedom

*** indicates a significant difference at 0.001 level based on a χ^2 test with 1 degree of freedom

Appendix 8: Differences in Primary and Secondary Student Perceptions Data

Student Mathematics Perceptions 2005 – Primary vs Secondary

Question	SA	SA + A
28 My teacher tries to help everyone understand maths/science	31.5	15.9***
12 What I learn in maths/science will be useful to me when I leave school	27.8	12.4***
15 My teacher expects everyone to do their best in maths/science	26.1	5.2***
36 What I learn in maths/science helps me in everyday life	25.4	20.5***
24 What I learn in maths/science will help me in the future	24.2	14.0***
13 We are encouraged to respect each other's ideas in my maths/science class	24.1	9.5***
30 My teacher tries to make maths/science interesting for everyone	23.4	24.9***
27 Sometimes the activities we do in maths/science are hard but they help us learn	23.1	8.6***
4 My teacher tries to find out what I know when teaching something new in maths/science	22.3	14.7***
35 I like to try hard with my maths/science work	20.6	5.7***
26 In my maths/science class we are encouraged to work things out for ourselves	19.0	7.9***
7 My teacher's comments on my maths/science work help me learn better	18.3	16.3***
23 I really want to do well in maths/science	17.8	0.9
25 My teacher values my work and ideas in maths/science	17.4	16.7***
14 My teacher expects me to think about how well I understand things	17.1	6.5***
29 In my maths/science class we often talk about our ideas	16.8	22.1***
31 My teacher gives me helpful feedback about my maths/science	16.2	16.5***
1 It is OK to say what I think in my maths/science class	16.2	16.0***
20 We learn about ways that maths/science is used in everyday life	16.1	14.4***
16 My teacher uses activities that help me understand new ideas	15.9	17.7***
34 I enjoy learning maths/science at my school	15.5	19.2***

2 In my maths/science class I am expected to make decisions about how I do my work	14.1	7.1***
10 I enjoy the work I do in my maths/science classes	12.5	20.4***
6 In maths/science we study things that interest me	11.2	21.2***
33 In maths/science we can use technology (such as computers, calculators or digital cameras) to help with our work	11.2	22.9***
22 Learning maths/science at my school is fun	10.4	22.0***
32 In my maths/science class we look at things in the news or work on problems that affect our lives	9.2	23.7***
11 I really want to learn about maths/science at school	9.0	9.4***
9 We use technology (such as computers, calculators or digital cameras) to explore new maths/science ideas	8.1	23.1***
5 I am expected to explain my thinking in maths/science	7.5	4.8*
3 The maths/science we do in class makes me think and ask questions	7.4	4.2*
21 We use technology (such as computers and calculators) to solve maths/science problems	6.6	14.8***
18 The maths/science we do is often connected to things I am interested in outside school	5.6	17.8***
8 In my maths/science class we work on projects outside school or have people come to talk to us	5.0	18.0***
17 In my maths/science class we do lots of investigations and problem solving	4.3	4.2
19 My teacher always tells us how our maths/science will be marked	-3.9	-13.6***

NOTES

1 SA represents the difference in percentages between primary and secondary students rating each item as Strongly Agree

2 SA + A represents the difference in percentages between primary and secondary students rating each item as Strongly Agree or Agree

* indicates a significant difference at 0.05 level based on a χ^2 test with 1 degree of freedom

** indicates a significant difference at 0.01 level based on a χ^2 test with 1 degree of freedom

*** indicates a significant difference at 0.001 level based on a χ^2 test with 1 degree of freedom

Student Science Perceptions 2005 – Primary vs Secondary

Question	SA	SA + A
28 My teacher tries to help everyone understand maths/science	22.1	9.1***
11 I really want to learn about maths/science at school	21.6	21.6***
13 We are encouraged to respect each other's ideas in my maths/science class	21.1	5.7***
12 What I learn in maths/science will be useful to me when I leave school	21.0	19.4***
34 I enjoy learning maths/science at my school	20.6	19.1***
27 Sometimes the activities we do in maths/science are hard but they help us learn	20.0	8.2***
30 My teacher tries to make maths/science interesting for everyone	19.7	16.7***
35 I like to try hard with my maths/science work	19.3	10.7***
15 My teacher expects everyone to do their best in maths/science	19.1	6.5***
22 Learning maths/science at my school is fun	19.1	20.1***
10 I enjoy the work I do in my maths/science classes	18.1	20.7***
4 My teacher tries to find out what I know when teaching something new in maths/science	16.4	14.1***
6 In maths/science we study things that interest me	16.3	19.5***
24 What I learn in maths/science will help me in the future	15.4	17.6***
8 In my maths/science class we work on projects outside school or have people come to talk to us	14.9	30.5***
26 In my maths/science class we are encouraged to work things out for ourselves	14.1	9.1***
23 I really want to do well in maths/science	13.9	4.8***
7 My teacher's comments on my maths/science work help me learn better	13.2	16.2***
29 In my maths/science class we often talk about our ideas	12.9	11.4***
36 What I learn in maths/science helps me in everyday life	12.8	23.3***
1 It is OK to say what I think in my maths/science class	12.0	5.7***
2 In my maths/science class I am expected to make decisions about how I do my work	11.8	6.0***

3 The maths/science we do in class makes me think and ask questions	11.5	7.0***
14 My teacher expects me to think about how well I understand things	10.9	11.4***
16 My teacher uses activities that help me understand new ideas	10.0	9.5***
33 In maths/science we can use technology to help with our work	9.5	4.5
25 My teacher values my work and ideas in maths/science	8.6	9.0***
31 My teacher gives me helpful feedback about my maths/science	7.9	10.1***
5 I am expected to explain my thinking in maths/science	7.7	7.0***
18 The maths/science we do is often connected to things I am interested in outside school	7.5	14.9***
32 In my maths/science class we look at things in the news or work on problems that affect our lives	6.7	20.3***
20 We learn about ways that maths/science is used in everyday life	6.3	-0.9
9 We use technology to explore new maths/science ideas	5.8	0.1
21 We use technology to solve maths/science problems	3.5	-1.8
17 In my maths/science class we do lots of investigations and problem solving	2.8	6.2*
19 My teacher always tells us how our maths/science will be marked	-2.2	-15.9***

NOTES

1 SA represents the difference in percentages between primary and secondary students rating each item as Strongly Agree

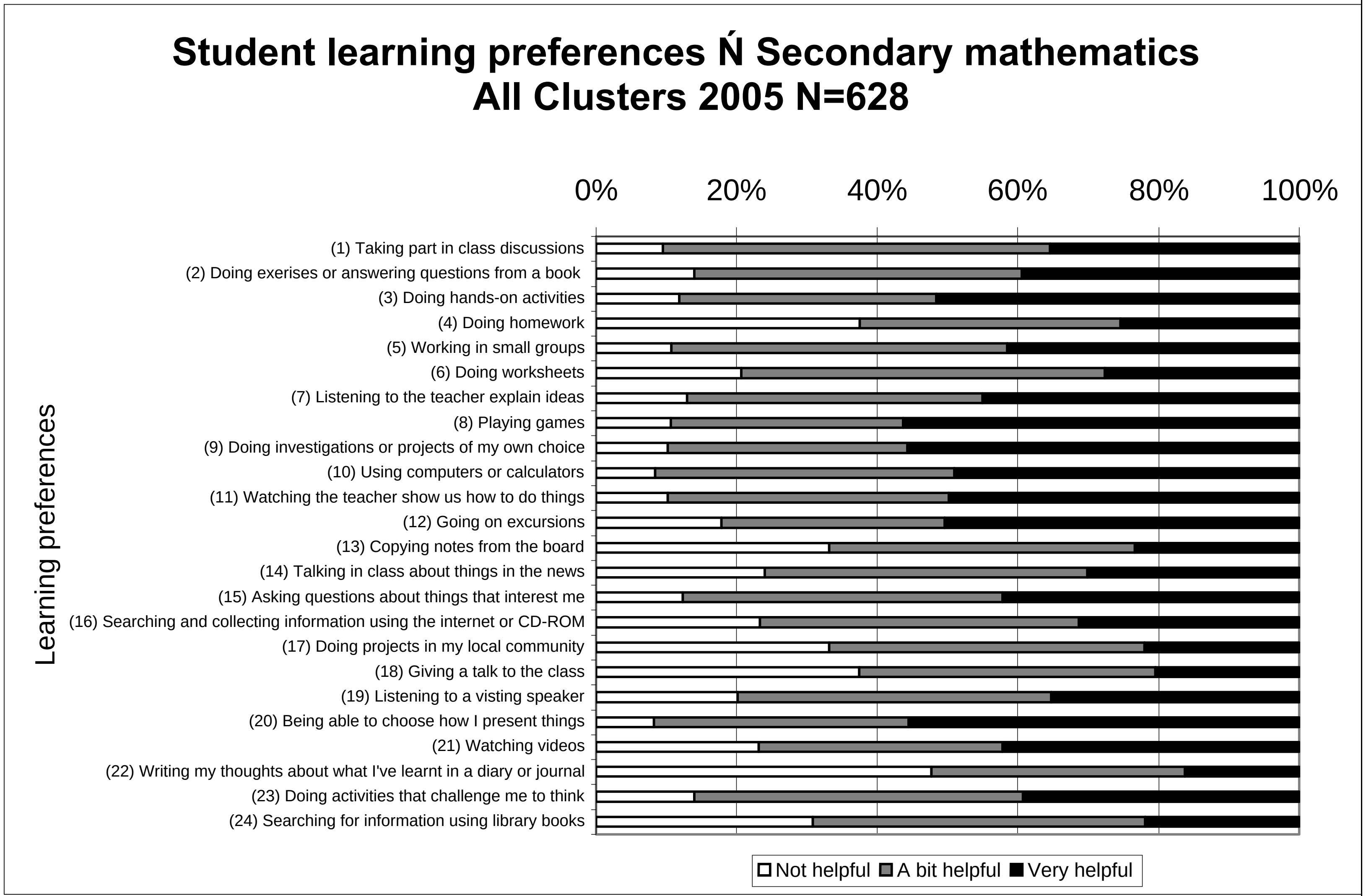
3 SA + A represents the difference in percentages between primary and secondary students rating each item as Strongly Agree or Agree

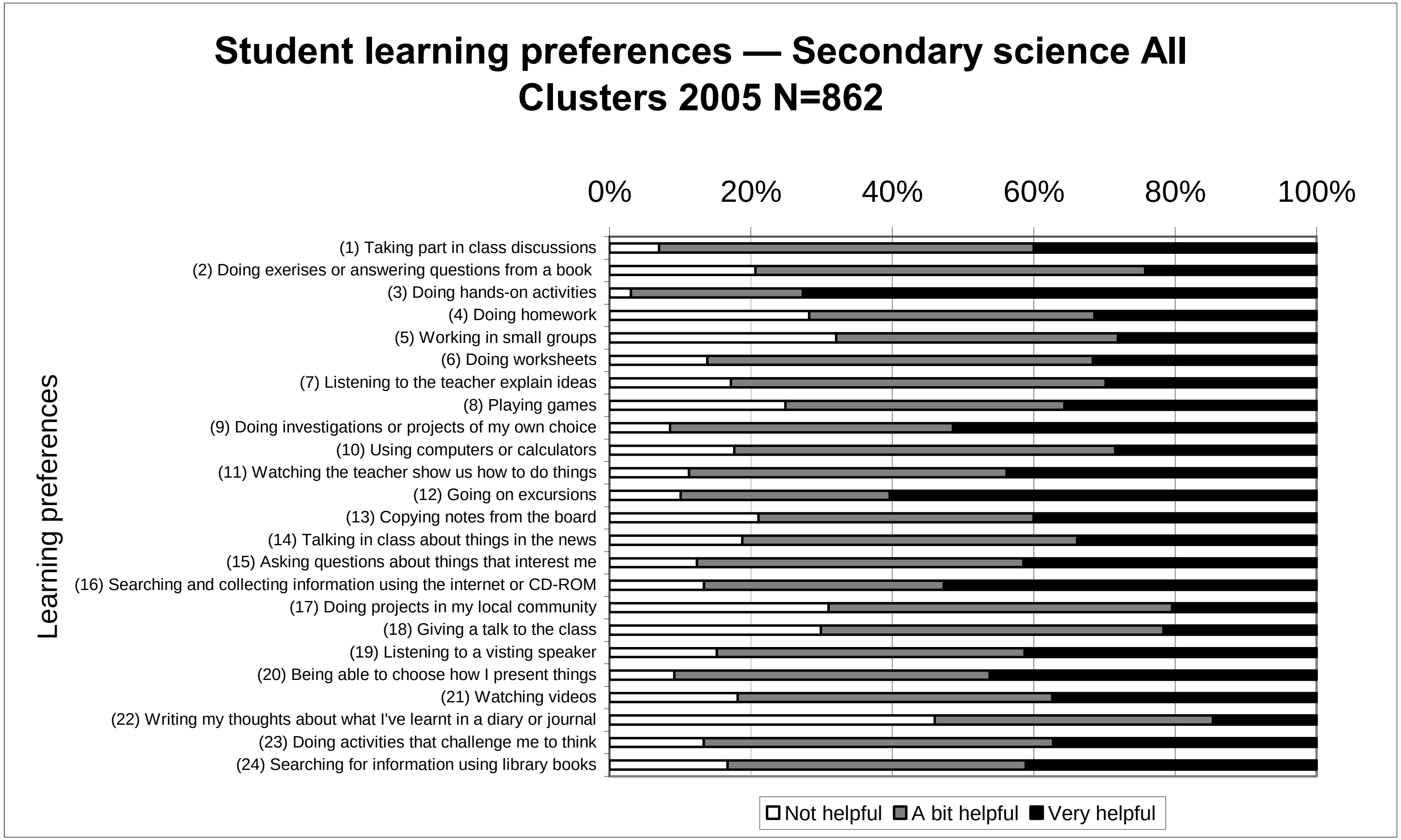
* indicates a significant difference at 0.05 level based on a χ^2 test with 1 degree of freedom

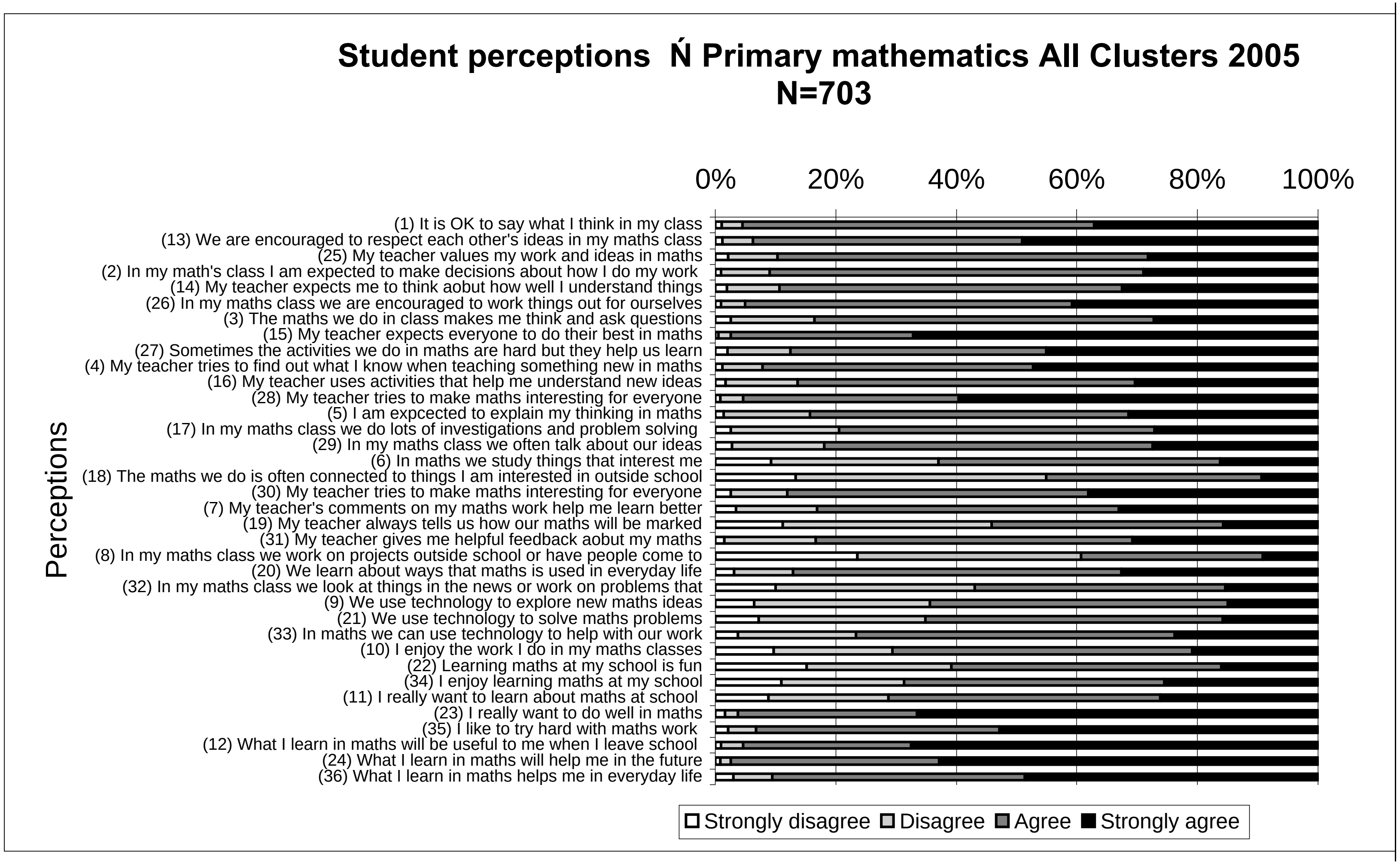
** indicates a significant difference at 0.01 level based on a χ^2 test with 1 degree of freedom

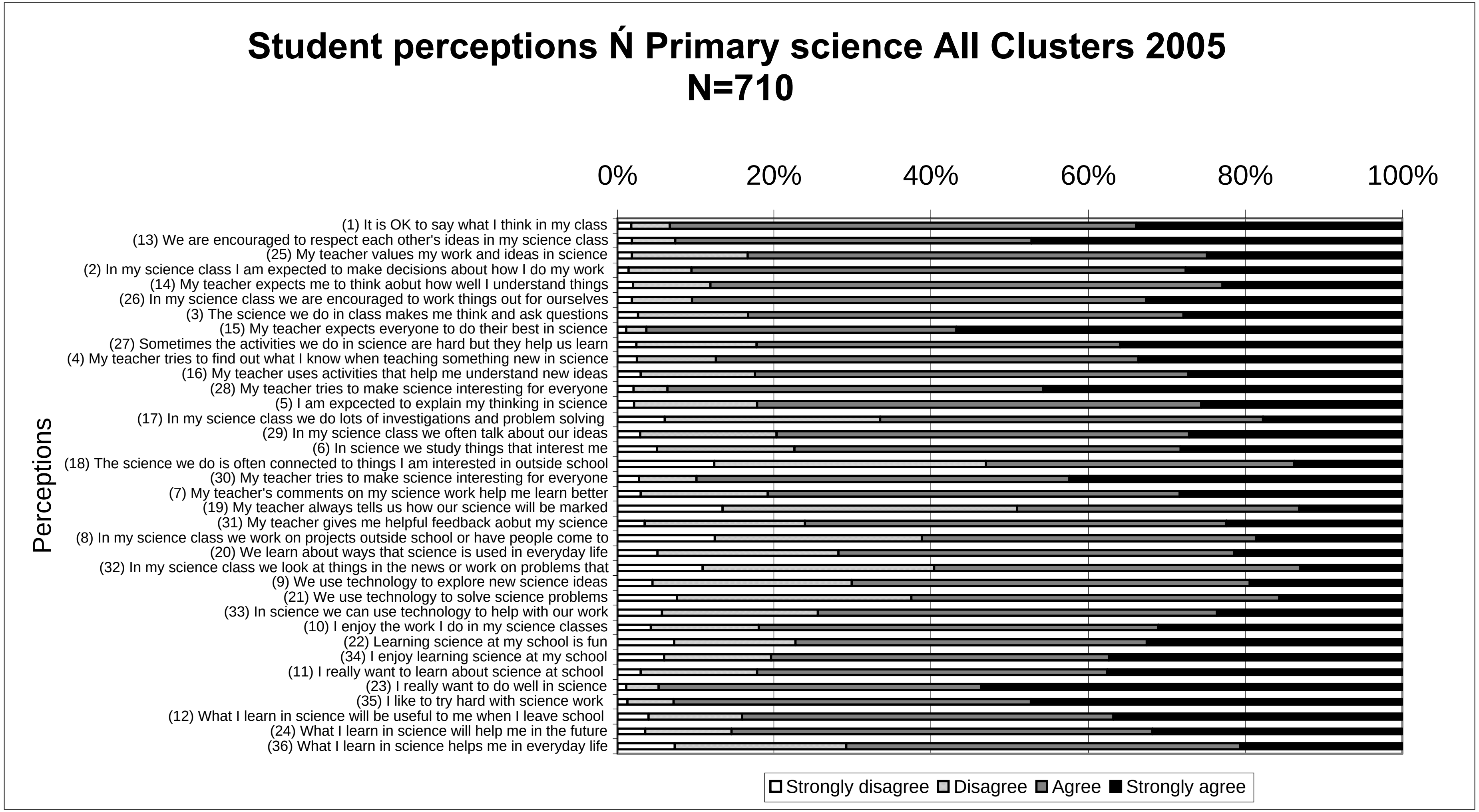
*** indicates a significant difference at 0.001 level based on a χ^2 test with 1 degree of freedom

Appendix 8: Student Learning Preference Data




Student learning preferences — Secondary science All Clusters 2005 N=862
0%
20%
40%
60%
80%
100%
Learning preferences
(1) Taking part in class discussions
(2) Doing exerises or answering questions from a book
(3) Doing hands-on activities
(4) Doing homework
(5) Working in small groups
(6) Doing worksheets
(7) Listening to the teacher explain ideas
(8) Playing games
(9) Doing investigations or projects of my own choice
(10) Using computers or calculators
(11) Watching the teacher show us how to do things
(12) Going on excursions
(13) Copying notes from the board
(14) Talking in class about things in the news
(15) Asking questions about things that interest me
(16) Searching and collecting information using the internet or CD-ROM
(17) Doing projects in my local community
(18) Giving a talk to the class
(19) Listening to a visting speaker
(20) Being able to choose how I present things
(21) Watching videos
(22) Writing my thoughts about what I've learnt in a diary or journal
(23) Doing activities that challenge me to think
(24) Searching for information using library books
Not helpful
A bit helpful
Very helpful


Student perceptions Ń Primary mathematics All Clusters 2005
N=703
0%
20%
40%
60%
80%
100%
Perceptions
(1) It is OK to say what I think in my class
(13) We are encouraged to respect each other's ideas in my maths class
(25) My teacher values my work and ideas in maths
(2) In my math's class I am expected to make decisions about how I do my work
(14) My teacher expects me to think aobut how well I understand things
(26) In my maths class we are encouraged to work things out for ourselves
(3) The maths we do in class makes me think and ask questions
(15) My teacher expects everyone to do their best in maths
(27) Sometimes the activities we do in maths are hard but they help us learn
(4) My teacher tries to find out what I know when teaching something new in maths
(16) My teacher uses activities that help me understand new ideas
(28) My teacher tries to make maths interesting for everyone
(5) I am expcected to explain my thinking in maths
(17) In my maths class we do lots of investigations and problem solving
(29) In my maths class we often talk about our ideas
(6) In maths we study things that interest me
(18) The maths we do is often connected to things I am interested in outside school
(30) My teacher tries to make maths interesting for everyone
(7) My teacher's comments on my maths work help me learn better
(19) My teacher always tells us how our maths will be marked
(31) My teacher gives me helpful feedback aobut my maths
(8) In my maths class we work on projects outside school or have people come to
(20) We learn about ways that maths is used in everyday life
(32) In my maths class we look at things in the news or work on problems that
(9) We use technology to explore new maths ideas
(21) We use technology to solve maths problems
(33) In maths we can use technology to help with our work
(10) I enjoy the work I do in my maths classes
(22) Learning maths at my school is fun
(34) I enjoy learning maths at my school
(11) I really want to learn about maths at school
(23) I really want to do well in maths
(35) I like to try hard with maths work
(12) What I learn in maths will be useful to me when I leave school
(24) What I learn in maths will help me in the future
(36) What I learn in maths helps me in everyday life
Strongly disagree
Disagree
Agree
Strongly agree


Student perceptions Ń Primary science All Clusters 2005
N=710
0%
20%
40%
60%
80%
100%
Perceptions
(1) It is OK to say what I think in my class
(13) We are encouraged to respect each other's ideas in my science class
(25) My teacher values my work and ideas in science
(2) In my science class I am expected to make decisions about how I do my work
(14) My teacher expects me to think aobut how well I understand things
(26) In my science class we are encouraged to work things out for ourselves
(3) The science we do in class makes me think and ask questions
(15) My teacher expects everyone to do their best in science
(27) Sometimes the activities we do in science are hard but they help us learn
(4) My teacher tries to find out what I know when teaching something new in science
(16) My teacher uses activities that help me understand new ideas
(28) My teacher tries to make science interesting for everyone
(5) I am expcected to explain my thinking in science
(17) In my science class we do lots of investigations and problem solving
(29) In my science class we often talk about our ideas
(6) In science we study things that interest me
(18) The science we do is often connected to things I am interested in outside school
(30) My teacher tries to make science interesting for everyone
(7) My teacher's comments on my science work help me learn better
(19) My teacher always tells us how our science will be marked
(31) My teacher gives me helpful feedback aobut my science
(8) In my science class we work on projects outside school or have people come to
(20) We learn about ways that science is used in everyday life
(32) In my science class we look at things in the news or work on problems that
(9) We use technology to explore new science ideas
(21) We use technology to solve science problems
(33) In science we can use technology to help with our work
(10) I enjoy the work I do in my science classes
(22) Learning science at my school is fun
(34) I enjoy learning science at my school
(11) I really want to learn about science at school
(23) I really want to do well in science
(35) I like to try hard with science work
(12) What I learn in science will be useful to me when I leave school
(24) What I learn in science will help me in the future
(36) What I learn in science helps me in everyday life
Strongly disagree
Disagree
Agree
Strongly agree

Appendix 9: Differences in Mathematics and Science Learning Preferences

Secondary Student Learning Preferences 2005 – Maths vs Science

Question	VH[1]
(8) Playing games	20.7
(10) Using computers or calculators	20.6
(2) Doing exercises or answering questions from a book	15.2
(7) Listening to the teacher explain ideas	15.2
(5) Working in small groups	13.4
(20) Being able to choose how I present things	9.3
(11) Watching the teacher show us how to do things	5.9
(21) Watching videos	4.7
(9) Doing investigations or projects of my own choice	4.4
(23) Doing activities that challenge me to think	2.0
(22) Writing my thoughts about what I've learnt in a diary or journal	1.6
(17) Doing projects in my local community	1.6
(15) Asking questions about things that interest me	0.8
(18) Giving a talk to the class	-1.2
(14) Talking in class about things in the news	-3.7
(6) Doing worksheets	-3.9
(1) Taking part in class discussions	-4.5
(4) Doing homework	-5.9
(19) Listening to a visiting speaker	-6.0
(12) Going on excursions	-10.0
(13) Copying notes from the board	-16.7
(24) Searching for information using library books	-19.2
(3) Doing hands-on activities	-21.0
(16) Searching and collecting information using the internet or CD-ROM	-21.4

1 VH represents the difference in percentages between secondary mathematics and science students rating each item as Very Helpful (i.e. % mathematics - % science)

Primary Student Learning Preferences 2005 – Maths vs Science

Question	VH[1]
(5) Working in small groups	18.6
(7) Listening to the teacher explain ideas	15.5
(8) Playing games	14.3
(20) Being able to choose how I present things	11.3
(10) Using computers or calculators	11.0
(23) Doing activities that challenge me to think	9.5
(17) Doing projects in my local community	7.5
(2) Doing exercises or answering questions from a book	6.4
(11) Watching the teacher show us how to do things	5.4
(12) Going on excursions	4.9
(9) Doing investigations or projects of my own choice	4.4
(1) Taking part in class discussions	2.1
(15) Asking questions about things that interest me	1.2
(14) Talking in class about things in the news	0.2
(4) Doing homework	-0.5
(21) Watching videos	-0.6
(18) Giving a talk to the class	-2.1
(3) Doing hands-on activities	-2.9
(22) Writing my thoughts about what I've learnt in a diary or journal	-6.9
(19) Listening to a visiting speaker	-7.5
(6) Doing worksheets	-7.8
(16) Searching and collecting information using the internet or CD-ROM	-9.3
(24) Searching for information using library books	-13.2
(13) Copying notes from the board	-17.5

1 VH represents the difference in percentages between primary mathematics and science students rating each item as Very Helpful (i.e. % mathematics - % science)

Appendix 10: Differences in Primary and Secondary Learning Preferences

Student Mathematics Learning Preferences 2005 – Primary vs Secondary

Question	VH[1]
(23) Doing activities that challenge me to think	20.7
(24) Searching for information using library books	15.9
(1) Taking part in class discussions	15.8
(3) Doing hands-on activities	12.8
(7) Listening to the teacher explain ideas	11.6
(16) Searching and collecting information using the internet or CD-ROM	11.5
(5) Working in small groups	10.5
(17) Doing projects in my local community	9.4
(6) Doing worksheets	9.1
(18) Giving a talk to the class	8.4
(15) Asking questions about things that interest me	8.4
(20) Being able to choose how I present things	8.3
(4) Doing homework	7.7
(12) Going on excursions	6.8
(11) Watching the teacher show us how to do things	5.7
(9) Doing investigations or projects of my own choice	5.5
(19) Listening to a visiting speaker	4.2
(10) Using computers or calculators	-0.1
(22) Writing my thoughts about what I've learnt in a diary or journal	-0.2
(13) Copying notes from the board	-0.3
(8) Playing games	-1.4
(14) Talking in class about things in the news	-1.6
(21) Watching videos	-2.5
(2) Doing exercises or answering questions from a book	-7.9

1 VH represents the difference in percentages between primary and secondary mathematics students rating each item as Very Helpful (i.e. % primary - %secondary)

Student Science Learning Preferences 2005 – Primary vs Secondary

Question	VH[1]
(23) Doing activities that challenge me to think	13.2
(6) Doing worksheets	12.9
(7) Listening to the teacher explain ideas	11.3
(24) Searching for information using library books	9.9
(10) Using computers or calculators	9.5
(18) Giving a talk to the class	9.3
(1) Taking part in class discussions	9.3
(22) Writing my thoughts about what I've learnt in a diary or journal	8.4
(15) Asking questions about things that interest me	8.0
(20) Being able to choose how I present things	6.3
(11) Watching the teacher show us how to do things	6.3
(19) Listening to a visiting speaker	5.7
(9) Doing investigations or projects of my own choice	5.5
(5) Working in small groups	5.3
(8) Playing games	4.9
(17) Doing projects in my local community	3.4
(21) Watching videos	2.9
(4) Doing homework	2.4
(2) Doing exercises or answering questions from a book	0.9
(13) Copying notes from the board	0.6
(16) Searching and collecting information using the internet or CD-ROM	-0.5
(3) Doing hands-on activities	-5.3
(14) Talking in class about things in the news	-5.5
(12) Going on excursions	-8.1

1 VH represents the difference in percentages between primary and secondary science students rating each item as Very Helpful (i.e. %primary - %secondary)

Appendix 11: Differences in Mathematics and Science Teacher Practice

Secondary Teacher Practice 2005 – Mathematics vs Science

IMYMS Sub-component	Maths 4 or 5 (%)	Science 4 or 5 (%)	Mathematics – Science (%)
1.1 Relations	73.0	86.2	-13.2*
1.2 Collaboration	27.0	65.5	-38.5***
1.3 Safe place	73.0	89.7	-16.7**
1.4 Effort valued	64.9	69.0	-4.1
2.1 Responsible learning	45.9	55.2	-9.2
2.2 Reflect on learning	37.8	48.3	-10.4
3.1 Conceptually complex	43.2	55.2	-11.9
3.2 Explore(challenge)	54.1	51.7	2.3
3.3 High expectations	83.8	86.2	-2.4
4.1 Explore current understanding	67.6	65.5	2.1
4.2 Individual needs	54.1	51.7	2.3
4.3 Connect key ideas	75.7	89.7	-14.0*
4.4 Sustained sequences	89.2	86.2	3.0
4.5 Interweaving concrete & abstract	51.4	79.3	-28.0***
5.1 Investigation & problem solving	48.6	75.9	-27.2***
5.2 Engage in reasoning	62.2	86.2	-24.0***
6.1 Student lives & interest	45.9	69.0	-23.0**
7.1 Feedback	67.6	51.7	15.8*
7.2 Assessing	56.8	62.1	-5.3
7.3 Criteria explicit	70.3	75.9	-5.6
8.1 Connect communities	5.4	10.3	-4.9
8.2 Rich view of practice	10.8	48.3	-37.5***
9 Learning technologies used	35.1	48.3	-13.1

NOTES

* indicates a significant difference at 0.05 level based on a χ^2 test with 1 degree of freedom

** indicates a significant difference at 0.01 level based on a χ^2 test with 1 degree of freedom

*** indicates a significant difference at 0.001 level based on a χ^2 test with 1 degree of freedom

Primary Teacher Practice 2005 – Mathematics vs Science

IMYMS Sub-component	Maths 4 or 5 (%)	Science 4 or 5 (%)	Mathematics – Science (%)
1.1 Relations	86.8	75.0	11.8*
1.2 Collaboration	63.2	66.7	-3.5
1.3 Safe place	89.5	83.3	6.1
1.4 Effort valued	64.9	74.3	-9.4
2.1 Responsible learning	64.9	74.3	-9.4
2.2 Reflect on learning	47.4	47.2	0.1
3.1 Conceptually complex	52.6	55.6	-2.9
3.2 Explore(challenge)	75.7	65.7	10.0
3.3 High expectations	86.5	80.0	6.5
4.1 Explore current understanding	81.6	69.4	12.1*
4.2 Individual needs	81.6	72.2	9.4
4.3 Connect key ideas	86.8	83.3	3.5
4.4 Sustained sequences	81.6	80.6	1.0
4.5 Interweaving concrete & abstract	63.2	52.8	10.4
5.1 Investigation & problem solving	71.1	66.7	4.4
5.2 Engage in reasoning	71.1	72.2	-1.2
6.1 Student lives & interest	65.8	72.2	-6.4
7.1 Feedback	76.3	72.2	4.1
7.2 Assessing	81.6	77.8	3.8
7.3 Criteria explicit	65.8	66.7	-0.9

8.1 Connect communities	15.8	22.2	-6.4
8.2 Rich view of practice	47.4	58.3	-11.0
9 Learning technologies used	39.5	44.4	-5.0

NOTES

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Appendix 12: Differences in Primary and Secondary Teacher Practice

Mathematics Teacher Practice 2005 – Primary vs Secondary

IMYMS Sub-component	Primary 4 or 5 (%)	Secondary 4 or 5 (%)	Primary – Secondary (%)
1.1 Relations	86.8	73.0	13.9*
1.2 Collaboration	63.2	27.0	36.1***
1.3 Safe place	89.5	73.0	16.5**
1.4 Effort valued	64.9	64.9	0.0
2.1 Responsible learning	64.9	45.9	18.9*
2.2 Reflect on learning	47.4	37.8	9.5
3.1 Conceptually complex	52.6	43.2	9.4
3.2 Explore(challenge)	75.7	54.1	21.6**
3.3 High expectations	86.5	83.8	2.7
4.1 Explore current understanding	81.6	67.6	14.0*
4.2 Individual needs	81.6	54.1	27.5***
4.3 Connect key ideas	86.8	75.7	11.2*
4.4 Sustained sequences	81.6	89.2	-7.6
4.5 Interweaving concrete & abstract	63.2	51.4	11.8
5.1 Investigation & problem solving	71.1	48.6	22.4**
5.2 Engage in reasoning	71.1	62.2	8.9
6.1 Student lives & interest	65.8	45.9	19.8*
7.1 Feedback	76.3	67.6	8.7
7.2 Assessing	81.6	56.8	24.8***
7.3 Criteria explicit	65.8	70.3	-4.5
8.1 Connect communities	15.8	5.4	10.4
8.2 Rich view of practice	47.4	10.8	36.6***
9 Learning technologies used	39.5	35.1	4.3

NOTES

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Science Teacher Practice 2005 – Primary vs Secondary

IMYMS Sub-component	Primary 4 or 5 (%)	Secondary 4 or 5 (%)	Primary – Secondary (%)
1.1 Relations	75.0	86.2	-11.2
1.2 Collaboration	66.7	65.5	1.1
1.3 Safe place	83.3	89.7	-6.3
1.4 Effort valued	74.3	69.0	5.3
2.1 Responsible learning	74.3	55.2	19.1**
2.2 Reflect on learning	47.2	48.3	-1.1
3.1 Conceptually complex	55.6	55.2	0.4
3.2 Explore(challenge)	65.7	51.7	14.0
3.3 High expectations	80.0	86.2	-6.2
4.1 Explore current understanding	69.4	65.5	3.9
4.2 Individual needs	72.2	51.7	20.5**
4.3 Connect key ideas	83.3	89.7	-6.3
4.4 Sustained sequences	80.6	86.2	-5.7
4.5 Interweaving concrete & abstract	52.8	79.3	-26.5***
5.1 Investigation & problem solving	66.7	75.9	-9.2
5.2 Engage in reasoning	72.2	86.2	-14.0*
6.1 Student lives & interest	72.2	69.0	3.3
7.1 Feedback	72.2	51.7	20.5**
7.2 Assessing	77.8	62.1	15.7*
7.3 Criteria explicit	66.7	75.9	-9.2
8.1 Connect communities	22.2	10.3	11.9
8.2 Rich view of practice	58.3	48.3	10.1
9 Learning technologies used	44.4	48.3	-3.8

NOTES

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