DOCUMENT RESUME

ED 370 767 SE 054 090

AUTHOR Fraser, Barry J., Ed.
TITLE Research Implications for Science and Mathematics Teachers. Volume 1. Key Centre Monograph Number 5.
INSTITUTION Curtin Univ. of Tech., Perth (Australia). National Key Centre for Science and Mathematics.
SPONS AGENCY Australian Dept. of Education, Canberra.
REPORT NO ISBN-1-86342-229-3
PUB DATE 93
NOTE 89p.
AVAILABLE FROM National Key Centre for School Science and Mathematics, Curtin University of Technology, GPO Box U 1987, Perth, Western Australia, Australia.
PUB TYPE Reports - Research/Technical (143) -- Guides - Non-Classroom Use (055) -- Tests/Evaluation Instruments (160)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Classroom Environment; Classroom Research; Demonstration Programs; Diagrams; *Educational Research; Elementary Secondary Education; Enrollment; Foreign Countries; *Mathematics Education; *Science Education; Science Experiments; Science Laboratories; Science Teachers; Teacher Student Relationship; *Technology Education; *Womens Education; Writing Exercises
IDENTIFIERS Australia

ABSTRACT

This document was compiled to help keep science and mathematics teachers in Australia abreast of the results of important research endeavors in education. The monograph is divided into 12 chapters. Chapter one, "Exemplary Science and Mathematics Teachers," (Barry Fraser and Kenneth Tobin) describes a study focusing on examples of outstanding teaching, thus providing a refreshing alternative to research which maligns science and mathematics education. Chapter two, "Assessing and Improving Classroom Environment," (Barry Fraser) includes a questionnaire and description of a questionnaire that can be used by teachers to obtain quick and easy assessment of their students' perceptions of classroom environment. Also included is a description of a case study of a teacher's successful application of a straightforward method for improving the environment of her classroom. Chapter three, "Scientific Diagrams: How Well Can Students Read Them? (Richard Lowe) provides two studies designed to question the assumptions that diagrams help students to learn science. Chapter four, "Images of Scientists: Gender Issues in Science Classrooms," (Jane Butler Kahle) discusses the long held image that students have of scientists and ways of changing these images. Chapter five, "Metaphors and Images in Teaching," (Kenneth Tobin) explains how metaphors and images are associated with salient teaching roles and belief sets. Chapter six, "Gender Equality in Science Classrooms," (Svein Sjoberg) provides examples to help describe the attitudes toward science and career choices of girls. Chapter seven, "Target Students," (Kenneth Tobin) discusses a five-year on-going research project that focuses on the manner in which students interact with teachers and with one another. Chapter eight, "Assessing the Climate of Science Laboratory Classes," (Barry Fraser, Geoffrey Giddings, and Campbell McRobbie) focuses on a questionnaire designed especially for assessing the climate of science laboratory classes. Chapter nine, "Writing in Mathematics Classes," (L. Dianne Miller) describes the benefits of writing in mathematics classes. Chapter ten, "Technology Education in Science and Mathematics," (Jan Harding and Leonnie Rennie) explores the concept of technology and the nature of technology education. Chapter eleven, "Teacher-Student Relationships in Science and Mathematics Classes," (Theo Wubbels) describes research based on studies that used the Questionnaire on Teacher Interaction to gather students' and teachers' perceptions of interpersonal teacher behavior. Chapter twelve, "Secondary Science and Mathematics Enrollment Trends," (John Malone, John deLaeter, and John Dekkers); reports on the magnitude of science and mathematics enrollment changes in Australia. (ZWH)

Key Centre Monograph Number 5

RESEARCH IMPLICATIONS FOR SCIENCE AND MATHEMATICS TEACHERS

Volume 1

Edited by

BARRY J. FRASER

Curtin University of Technology
Perth Western Australia

National Key Centre for School Science and Mathematics

RESEARCH IMPLICATIONS FOR SCIENCE AND MATHEMATICS TEACHERS

Volume 1

Edited by

Barry J. Fraser
Curtin University of Technology

Monograph Number 5 published by the national Key Centre for School Science and Mathematics (Especially for Women) at Curtin University of Technology

40404-3-93

This monograph was published by the national Key Centre for Teaching and Research in School Science and Mathematics (Especially for Women) at Curtin University of Technology. This Key Centre, which is funded by the Commonwealth Government, sponsors extensive postgraduate, educational research, publication and teacher professional development programs. The Centre aims to improve the quality of, and participation in, school science and mathematics, especially among girls. The Key Centre sponsors visits from eminent overseas scholars who assist in its research and teacher professional development activities. The Key Centre's address is

National Key Centre for School Science and Mathematics
Curtin University of Technology
GPO Box U 1987
Perth, Western Australia 6001

Telephone: 09 351 7896
Fax: 09 351 2503
Electronic Mail: NTANNERTD@cc.curtin.edu.au

International Standard Book Number
ISBN 1 86342 229 3

TABLE OF CONTENTS

(cont.)

TABLE OF CONTENTS (continued)

(cont.)

TABLE OF CONTENTS (continued)

Page

EDITOR'S PREFACE

The national Key Centre for School Science and Mathematics at Curtin University of Technology is funded by the Australian Federal Government as a centre of excellence in science and mathematics education. The Key Centre sponsors extensive graduate studies, professional development, research and publication programs.

One of the most successful aspects of the Key Centre's publication program has proved to be its *What Research Says to the Science and Mathematics Teacher* series. These publications aim to bring the results of important research endeavours to the attention of busy science and mathematics teachers. In order to appeal to busy teachers, these publications are relatively brief, avoid jargon and are produced in attractive format. The *What Research Says ...* series has been distributed free of charge to all secondary schools throughout Australia.

Now that the first 12 issues in the *What Research Says ...* series have been completed, it is timely to make the series readily available to a variety of Australian and overseas audiences. Consequently, the 12 issues are now being published as the present monograph. It is envisaged that this convenient collection of 12 chapters, which describe a variety of research studies with practical implications for science and mathematics teachers, will be particularly useful in teacher education programs.

BARRY J. FRASER
Curtin University of Technology
March 1993

LIST OF CONTRIBUTORS

Dr Barry J. Fraser is Professor of Education, Director of the Science and Mathematics Education Centre and Director of the national Key Centre for School Science and Mathematics at Curtin University of Technology.

Dr Richard K. Lowe is Senior Lecturer in Education at Curtin University of Technology.

Dr Jane Butler Kahle is the Condit Professor of Science Education at Miami University, Oxford, Ohio, 45056-1693, USA. She is a consultant to the Key Centre in the area of gender issues in science and mathematics education.

Dr Kenneth Tobin is Professor of Education and coordinator of the science education program at Florida State University, Tallahassee, Florida 32306, USA.

Dr Svein Sjøberg is Associate Professor at the Centre for Science Education, University of Oslo, PO Box 1099 Blindern, 0316 Oslo 3, Norway.

Dr Geoffrey J. Giddings is Associate Professor of Education at Curtin University of Technology.

Dr Campbell J. McRobbie is Acting Director of the Centre for Mathematics and Science Education at Queensland University of Technology, Kelvin Grove Campus, Locked Bag No. 2, Red Hill, Queensland 4059.

Dr L. Diane Miller is Associate Professor at the College of Education, Texas Tech University, Lubbock, Texas 79409-1071, USA.

Dr Jan Harding is an Equity Consultant in Science and Technology at Airesford, Hampshire, UK.

Dr Léonie J. Rennie is Associate Professor at the national Key Centre for School Science and Mathematics at Curtin University of Technology.

Dr Theo Wubbels is Professor of Education in the Institute of Education at the University of Utrecht, PO Box 80127, 3508 TC Utrecht, The Netherlands.

Dr John A. Malone is Associate Professor at the national Key Centre for School Science and Mathematics at Curtin University of Technology.

Professor John R. de Laeter is Deputy Vice-Chancellor of Research and Development at Curtin University of Technology, and is a Fellow of the Australian Academy of Technological Sciences and Engineering and of the Australian and British Institutes of Physics.

Professor John Dekkers is Director, Department of External and Continuing Education at the University of Central Queensland, Rockhampton, Queensland, 4700, Australia.

Chapter 1

EXEMPLARY SCIENCE AND MATHEMATICS TEACHERS

Barry J. Fraser
Curtin University of Technology, Western Australia

Kenneth Tobin
Florida State University, United States of America

What is it about educational research and educational policy reports that inevitably leads to conclusions that the quality of science and mathematics education needs to improve substantially? Is it the nature of educational research to highlight aspects of teaching and learning that must be improved? Or is it that researchers and report writers typically focus on what needs to be improved rather than what already is being done very well?

Some of the common pessimistic findings from past research are that classrooms are dominated by the teacher's lecturing and the use of textbooks, and that little attention is given to applications in daily life or to the development of higher-order thinking skills (Goodlad, 1984; Stake & Easley, 1978). Although there is little doubt that the findings of research in science and mathematics education can be depressing at times, it would be a serious mistake to assume that all research yields disappointing results. Quite on the contrary, the study described here provides a refreshing alternative to research which maligns science and mathematics education by focusing on outstanding examples of teaching.

DESCRIPTION OF THE STUDY

Our study was known as the *Exemplary Practice in Science and Mathematics Education* study (Tobin & Fraser, 1987, 1990). Its focus was exemplary teaching and the positive facets of science and mathematics education. Because it was assumed that a great deal could be learned from the good things that teachers do, a study of exemplary science and mathematics teachers was undertaken to identify what it is that makes them so good.

Teachers rarely get to see good teaching in the ˎsses of others, often because they are too busy in their own classrooms. So, we studied the teaching practices of teachers who were recognised as good teachers, in the hope that we would be able to describe what they did and that other teachers might learn from their classroom practices.

The inspiration for the *Exemplary Practice in Science and Mathematics Education* project grew out of a project entitled the *Search for Excellence* (Penick & Yager, 1983), based at the University of Iowa and sponsored by the National Science Teachers' Association and other organisations in the USA. The rationale for the American project was that a focus on successful science programs holds hopes for improving practice. The obvious enthusiasm, optimism and excitement generated by the *Search for Excellence* encouraged a research team based at Curtin University to embark on a similar study in Western Australia.

This research on exemplary practice involved a total of 13 researchers from Curtin and other institutions in Perth. The study focused on 22 exemplary teachers and a comparison group of non-exemplary teachers. Of these 22 teachers, seven taught mathematics (two secondary and five primary), six taught senior-school biology, chemistry or physics, four taught junior secondary science and five taught primary science. Seven of the exemplary teachers were women.

The exemplary teachers were identified by asking other teachers, Ministry of Education advisory staff and tertiary institution staff to nominate teachers whom they considered to be outstanding. We did not provide our own definition of 'outstanding', nor did we ask these people to spell out the criteria which they used in making their nominations. Teachers were only selected for the study if they had been nominated as outstanding by several different people.

The *Search for Excellence* in the USA had a focus on exemplary programs and involved the study, evaluation and dissemination of program descriptions. In contrast, the focus in the Western Australian study was on the classroom practices employed by exemplary teachers. Consequently, the Au n researchers carried out intensive classr ervation of exemplary teaching and interviewed teachers and students. Altogether, the researchers were involved in over 500 hours of classroom observation. The researchers took field notes during their classroom visits and these were discussed, analysed and interpreted during regular meetings of the research team. In addition, students completed questionnaires to provide their opinions about their classroom environments.

FINDINGS

In some respects, the most valuable contributions of this study are the eleven detailed case studies of exemplary teachers of science and mathematics at various grade levels. In addition, the findings from the individual case studies have been synthesised to identify characteristics common to all of the exemplary teachers. Although not all of the exemplary teachers taught in the same way, nevertheless some patterns of behaviour were common to all exemplary teachers, irrespective of the subject or grade level taught. Consequently, emphasis on these behaviours is likely to improve other teachers' teaching. Some of these characteristics are discussed below.

Classroom Management

A common feature of exemplary science and mathematics teachers was that they managed their classrooms effectively. The teachers actively monitored student behaviour in their classes by moving around the room and speaking with individuals from time to time. Also they maintained control-at-a-distance over the entire class. Little evidence of student misbehaviour was noted. Students were able to work independently and cooperatively in groups.

Interestingly, many of the teachers listed the development of autonomy and independence among their goals. Because students understood the rules and worked within them, there was no need for the teacher to devote much time at all to handling student behaviour problems. Students knew what to do, because teachers communicated expectations clearly, and appeared to enjoy working in the classroom. Of course, it is likely that teachers had established clear classroom rules prior to the researchers' observations.

In order for teachers to be able to monitor understanding successfully, it is necessary for students to be well-behaved and cooperative. Although the exemplary teachers in our study usually did not have the easiest classes in their schools, still they appeared able to manage student behaviour easily. In most classes taught by exemplary science and mathematics teachers, students demonstrated a capacity to work together if problems arose, to seek help from a peer or to wait for the teacher to provide assistance. Consequently, teachers were not under pressure to maintain order, nor were they rushing from one student to another at the request of students experiencing difficulties. Rather, the teachers had time to consider what to do next and to reflect on the lesson as it progressed. Most exemplary teachers appeared to monitor student engagement and understanding in a thoughtful, systematic and routine manner.

For example, we observed one of the exemplary mathematics teachers exhibiting fine management skills. Through a blend of encouragement and firmness, the teacher communicated her expectations of pupil behaviour. Although she allowed students to chat a little during individualised and small-group activities, students were not permitted to talk or move about during whole-class work. This teacher also insisted that only one student spoke at a time during class discussions.

Emphasis on Student Understanding

Most exemplary teachers in our study used strategies aimed at assisting students to learn with understanding. All exemplary teachers provided activities in which students could get involved. In primary school grades, the activities were based on the use of materials to solve problems and, at the high school level, teachers often used concrete examples for abstract concepts. The key to teaching with understanding was the verbal interaction which enabled teachers to monitor student understanding of science and mathematics concepts.

The exemplary science and mathematics teachers were effective in a range of verbal strategies, including asking questions to stimulate thinking, probing student responses for clarification and elaboration, and providing explanations which gave students additional information. For example, in one of our case studies involving three exemplary primary science teachers, a materials-centred and problem-solving emphasis allowed students to make and test predictions. Also, students were encouraged to discuss their findings with their classmates and the teacher, and the teachers' questions in small-group and whole-class activities were of high quality. The teachers knew which questions to ask in order to facilitate important understandings about science.

Similarly, exemplary high school teachers provided activities which promoted understanding. For example, an exemplary biology teacher emphasised inquiry rather than verification of facts and principles, and was a model inquiry teacher, not only in the way in which he asked questions but also in the way in which he encouraged students to think for themselves and to ask questions.

An exemplary Year 6 mathematics teacher in our study emphasised problem-solving rather than merely getting the right answer. She believed that students learn by doing and, so, manipulative materials were commonly used by the teacher and were readily available for students to use during small-group and individualised activities. This teacher constantly monitored students' involvement and understanding and provided relevant feedback.

Favourable Classroom Learning Environment

In addition to the information collected by observation and interview, questionnaires were administered to find out what students thought about the learning environments (Fraser, 1986) of classes taught by exemplary teachers and those taught by a comparison group of non-exemplary teachers. These instruments provided some quantified information about exemplary teachers' classrooms and helped us to see classrooms through the students' eyes.

All of the case studies indicated that students of exemplary teachers perceived their classroom environments as being good places for learning. For example, both classes of an exemplary biology teacher perceived their actual classroom climate considerably more favourably than the way in which students taught by non-exemplary teachers viewed their science classes.

The biggest differences occurred for involvement (the extent to which students participate and show interest in class activities), teacher support (the extent to which the teacher helps, befriends and is interested in the students) and order and organisation (the extent to which classroom activities run smoothly, and students behave in an orderly way). In addition, in classes taught by exemplary teachers, there was a surprising similarity between the kind of classroom environment that students would like and the classroom environment which they were actually in.

Strong Content Knowledge

The research highlighted numerous times the importance of the teacher's content knowledge. In most of the lessons which we observed, exemplary teachers displayed strong knowledge of their content area, and this enhanced their teaching. But the importance of content knowledge also was illustrated in a negative sense with one of our exemplary teachers. In one case study, an exemplary secondary school teacher made several errors while teaching a general science topic which was out of his field. The net result of the teacher's lack of content knowledge was an emphasis on learning of facts and the development of misconceptions. Moreover, these instances of teachers having less than optimal backgrounds in the content to be taught occurred in classes of teachers who had been nominated as exemplary. Such problems are likely to be of greater significance in the classes of non-exemplary teachers.

Encouraging Student Participation

Another common characteristic of exemplary teachers' classes was the encouragement given to all students to be actively involved in classroom discussions and activities. By avoiding sarcasm or ridicule, teachers made it 'safe' for students to 'have a go' at answering questions or doing activities.

For example, we observed that one of the exemplary mathematics teachers moved from one student to another during individualised work to provide assistance. The physical distance between student and teacher was small and the teacher spoke softly. Consequently, conversations were fairly private and did not disrupt the rest of the class. This technique convinced students that even the most trivial questions would be received in a sympathetic and caring manner and would not be publicised to the whole class. Furthermore, the rest of the students in the class benefitted by not having their concentration broken.

CONCLUSIONS

What was learned from the case studies of exemplary practice was not all that surprising, nor did it provide grounds for total optimism. The exemplary teachers managed their classes well, taught with student understanding as a focus, encouraged students to participate actively, and maintained classroom environments that were conducive to learning. As well, they had a sound grasp of the content that students were to learn. Because no one of these factors alone was sufficient for effective teaching, the study highlights the complex nature of teaching and learning. Clearly, effective teaching requires much more than presenting content from textbooks. Consequently, preservice and continuing teacher education have an important role to play in helping teachers to develop some of the teaching skills that are found in exemplary teachers' classes.

In order to promote student understanding, exemplary teachers' questions were used skilfully to focus student engagement and to probe for misunderstandings. When explanations were given, they were clear and appropriate. Concrete examples often were used to illustrate abstract concepts and analogies and examples from outside the classroom were used frequently to facilitate understanding. In addition, teachers appeared to anticipate areas of content likely to provide students with problems. At the conclusion of a lesson, the main points were highlighted and revised prior to the close of the lesson.

Quite clearly, exemplary teachers had extensive knowledge of how students learned as well as what to teach and how best to teach it. The findings are a salient reminder that teaching is a demanding profession. Without both the necessary content and pedagogical knowledge, teachers can expect to flounder. And those who are experiencing difficulties can anticipate continuing problems unless they attain mastery over what they are teaching and how to teach it.

Even in a study of exemplary teachers, weaknesses in content knowledge were found to cause problems. Therefore, administrators should be loathe to schedule teachers for out-of-field teaching assignments. Willing and dedicated teachers can expect to experience considerable problems if they are required to teach in areas in which they have inadequate content knowledge. Often it is felt that there are few alternatives because suitably qualified science and mathematics teachers are in short supply. But it should be recognised that the apparently common practice of meeting needs within a school by having teachers teach outside their main fields creates problems for students.

The main implication for teacher educators is that there is a need to identify the discipline-specific knowledge required by science and mathematics teachers, and to help them to acquire this knowledge in a form that can be used in the classroom. Furthermore, there is much to be learned from exemplary science teachers which can be of benefit to others. Perhaps the most fruitful area relates to the activities and strategies used to teach specific areas of science content. Detailed case studies which describe activities in terms of teacher and student involvement in learning tasks can serve as the content of science and mathematics teacher education courses. For example, case studies would provide descriptions of hands-on activities, examples of key questions asked by the teacher to stimulate thinking, and a variety of student responses which indicate complete understanding, partial understanding, and misunderstanding of specific concepts. Classroom researchers and teacher educators should work together with exemplary teachers to begin the task of creating a case history for science and mathematics education.

The *Exemplary Practice in Science and Mathematics Education* study suggested some models of teaching which all science and

mathematics teachers can adopt. In this sense, the study provides grounds for optimism about the future of science and mathematics education. In addition, the analysis of exemplary teaching revealed an Achilles heel which needs the close attention of all science and mathematics educators. Additional resources probably are needed to assist teachers to obtain the knowledge needed to teach specific science and mathematics content. Provision of these resources to all science and mathematics teachers, as well as convincing them that knowledge limitations might be inhibiting their teaching effectiveness, represent substantial problems for all educators of science and mathematics teachers.

REFERENCES

Fraser, B J. (1986). *Classroom environment.* London, England: Croom Helm.

Goodlad, J. I. (1984). *A place called school: Prospects for the future.* New York: Macmillan.

Penick, J. E., & Yager, R. E. (1983). The search for excellence in science education. *Phi Delta Kappan, 64*, 621-623.

Stake, R. E., & Easley, J. A. (1978). *Case studies in science education.* Urbana, IL: Center for Instructional Research and Curriculum Evaluation and Committee on Culture and Cognition, University of Illinois.

Tobin, K., & Fraser, B. J. (Eds.). (1987). *Exemplary practice in science and mathematics education.* Perth, Western Australia: National Key Centre for School Science and Mathematics, Curtin University of Technology.

Tobin, K., & Fraser, B. J. (1990). What does it mean to be an exemplary science teacher. *Journal of Research in Science Teaching, 27*, 3-25.

Chapter 2

ASSESSING AND IMPROVING CLASSROOM ENVIRONMENT

Barry J. Fraser
Curtin University of Technology, Western Australia

Students spend a vast amount of time, in the order of 15 000 hours, in school classrooms during primary and secondary schooling. Consequently, the quality of life in these classrooms is of great importance and students' reactions to and perceptions of their school experiences are significant.

Teachers often speak of a classroom's climate, environment, atmosphere, tone, ethos or ambience and consider it to be both important in its own right and influential in terms of student learning. It would be rare, however, for science and mathematics teachers to include classroom environment measures among their evaluation procedures. Typically, teachers concentrate almost exclusively on the assessment of academic achievement, and devote little attention to factors which might be related to their students' performance.

Although classroom environment is a somewhat subtle concept, remarkable progress has been made over the last two decades in conceptualising, assessing and researching it. This research has attempted to answer many questions of interest to science and mathematics teachers. Does a classroom's environment affect student learning and attitudes? Can teachers conveniently assess the climates of their own classrooms and can they change these environments? Is there a difference between actual and preferred classroom environment, as perceived by students, and does this matter in terms of student outcomes. Do teachers and their students perceive the same classroom environments similarly? What is the impact of a new curriculum or teaching method on classroom environment? Do students of different abilities, genders or ethnic backgrounds perceive the same classroom differently? These questions represent the thrust of the work on classroom environments over the past 20 years (see reviews by Fraser, 1986, 1989, in press; Fraser & Walberg, 1991).

Although much research has been conducted on student perceptions of classroom learning environment, surprisingly little has been done to help science and mathematics teachers assess and improve the environments of their own classrooms. Consequently, the basic purpose of the present chapter is to inform science and mathematics teachers about this work, and to make available to them a questionnaire for assessing classroom environment.

A description is given of a convenient classroom environment questionnaire which can be used by teachers to obtain a quick and easy assessment of their students' perceptions of classroom environment. A complete copy of this questionnaire, in a form that may be reproduced by teachers for use in their own classrooms, is provided in Supplements A and B. Also, a description is given of a case study of a teacher's successful application of a straightforward method for improving the environment of her classroom.

ASSESSMENT OF CLASSROOM ENVIRONMENT

Despite the fact that the original form of several instruments measuring student perceptions of classroom environment has proved useful for various research purposes, experience has shown that many teachers would prefer an assessment method which is more economical in terms of the time required for administration and scoring. Consequently, a short version of several scales was developed to satisfy two main criteria (Fraser & Fisher, 1983). First, the number of items is reduced to provide greater economy in testing and scoring time. Second, because many teachers do not have ready access to computerised scoring methods, the short form is amenable to easy hand scoring.

Supplement A contains the short version of one classroom environment questionnaire, called the *My Class Inventory (MCI)*, which is well-suited for use at the primary and lower secondary school levels because of the low reading levels of its items. This instrument is economical in that it measures five different dimensions, yet contains only 25 items altogether. The simple *Yes-No* response format makes the questionnaire easy for students to answer. Students' answers are recorded on the questionnaire itself to avoid errors that can arise in transferring responses to a separate answer sheet. With a one-page questionnaire, printing costs are minimised and neither collation nor stapling is necessary.

The items shown in Supplement A are arranged in cyclic order and in blocks of five to enable ready hand scoring. The first item in each block assesses *Satisfaction (S)*; the second item in each block assesses *Friction (F)*; the third item assesses *Competitiveness (Cm)*; the fourth item assesses *Difficulty (D)*; and the last item in each block assesses *Cohesiveness (Ch)*. The meaning of these scales can be clarified simply by examining the items they contain.

In order to score most items, *3* is given for the *Yes* response and *1* is given for the *No* response. But, for the items with *R* in the *For Teacher's Use* column, reverse scoring is used so that *3* is given for *No* and *1* is given for *Yes*. Omitted or incorrectly answered items are given a score of 2. The score for each of the 25 individual items can be written in the *For Teacher's Use* column.

The total score for a particular scale is simply the sum of the scores for the five items belonging to that scale. For example, the Satisfaction scale total is obtained by adding the scores given to Items 1, 6, 11, 16 and 21, whereas the Cohesiveness total is the sum of the scores obtained for the last item in each block. The bottom of the questionnaire provides some spaces where the teacher can record the student's total score for each scale. Figure 1 shows how the questionnaire was scored to obtain a total of 10 for the Satisfaction scale and 12 for the Cohesiveness scale.

In addition to a form which measures perceptions of *actual* environment, the MCI has an additional form which measures *preferred* environment. The preferred form is concerned with goals and value orientations as it measures perceptions of the environment ideally liked or preferred. As the proposed method for attempting to change classrooms involves students' perceptions of preferred environment, a preferred form of the short version of the MCI was needed. Although item wording is almost identical for actual and preferred forms, the directions for answering the two forms need to instruct students clearly as to whether they are rating what their class is actually like or what they would prefer it to be like. Supplement B contains the preferred form. It can be seen that an item such as "My class is fun" in the actual form is changed to "My class *would be* fun" in the preferred form.

Information about the reliability of the short form of MCI scales is available for an Australian sample consisting of 758 third grade students in 32 classes in eight schools located in the Sydney metropolitan area (Fraser & O'Brien, 1985). Both the actual and preferred forms were administered orally to these students by a research assistant (because it was thought that reading difficulties could be experienced by students at this age level). For this sample, reliabilities for class means (alpha coefficients) for the actual form were 0.68 for Satisfaction, 0.78 for Friction, 0.70 for Competitiveness, 0.58 for Difficulty and 0.81 for Cohesiveness, and for the preferred form were 0.75 for Satisfaction, 0.82 for Friction, 0.77 for Competitiveness, 0.60 for Difficulty and 0.78 for Cohesiveness. These values indicate that the short form of the MCI has satisfactory reliability for scales containing only five items each.

A METHOD FOR IMPROVING CLASSROOM ENVIRONMENT

Fraser (1981) has proposed a simple approach by which teachers can use information obtained from classroom environment questionnaires to guide attempts to improve their classrooms. The basic approach involves two aspects. First, assessments of student perceptions of both their actual and preferred classroom environment are used to identify differences between the actual classroom environment and that preferred by students. Second, strategies aimed at reducing these differences are implemented. An example of the use of these methods in a secondary science class is described by Fraser and Fisher (1986) and an example involving a mathematics class is contained in Fraser, Malone and Neale (1989).

In the paragraphs below, a case study is reported of the use of the actual and preferred forms of the short version of the MCI by a teacher who was attempting to improve the environment of her classroom. This class consisted of 26 Grade 6

*Remember you are describing your **actual** classroom*	Circle Your Answer	For Teacher's Use
1. The pupils enjoy their schoolwork in my class.	(Yes) No	3
2. Pupils are always fighting with each other.	Yes No	___
3. Pupils often race to see who can finish first.	Yes No	___
4. In my class the work is hard to do.	Yes No	___
5. In my class everybody is my friend.	Yes (No)	1
6. Some pupils are not happy in my class.	(Yes) No	R 1
7. Some pupils in my class are mean.	Yes No	___
8. Most pupils want their work to be better than their friend's work.	Yes No	___
9. Most pupils can do their schoolwork without help.	Yes No	R ___
10. Some pupils in my class are not my friends.	Yes (No)	R 3
11. Pupils seem to like my class.	Yes (No)	1
12. Many pupils in my class like to fight.	Yes No	___
13. Some pupils feel bad when they don't do as well as the others.	Yes No	___
14. Only the smart pupils can do their work.	Yes No	___
15. All pupils in my class are close friends.	(Yes) (No)	2
16. Some pupils don't like my class.	Yes (No)	R 3
17. Certain pupils always want to have their own way.	Yes No	___
18. Some pupils always try to do their work better than the others.	Yes No	___
19. Schoolwork is hard to do.	Yes No	___
20. All pupils in my class like one another.	(Yes) No	3
21. My class is fun.	Yes No	2
22. Pupils in my class fight a lot.	Yes No	___
23. A few pupils in my class want to be first all of the time.	Yes No	___
24. Most pupils in my class know how to do their work.	Yes No	R ___
25. Pupils in my class like each other as friends.	(Yes) No	3

For Teacher's Use Only: S 10 F ___ Cm ___ D ___ Ch 12

FIGURE 1. Illustration of Hand Scoring Procedures

students of lower ability at a coeducational government school in a suburb of Sydney. This teacher took the class for science and mathematics, as well as for other subjects.

The procedure followed by the teacher of this class incorporated the following five fundamental steps:

1. **Assessment**. The MCI was administered to all students in the class. The preferred form was answered first, while the actual form was administered a couple of days later. Students in this sixth grade sample found the MCI easy to read.

2. **Feedback**. The teacher generated feedback information based upon student responses. Student responses were hand scored and class mean scores were used to construct the profiles shown in Figure 2, which represent the means of students' actual and preferred environment scores. The teacher found that these profiles provided a particularly useful and clear way of summarising the data. In particular, the profiles permitted ready identification of which aspects of classroom environment needed to be changed in order to reduce major differences between the actual environment and preferred environment as currently perceived by students. Figure 2 shows that the larger differences occurred for Friction, Competitiveness and Cohesiveness. Students preferred less Friction, less Competitiveness and more Cohesiveness.

3. **Reflection and Discussion**. The teacher thought about the profiles and discussed them with colleagues. This further clarified the interpretation and implications of the profiles and helped her to decide whether to try to change the classroom environment in terms of some of the MCI's scales. The main criteria used for selection of dimensions for change were, first, that there should exist a sizeable actual-preferred difference on that variable and, second, that *the teacher should feel concerned about this difference and want to make an effort to reduce it.* These considerations led the teacher to decide to introduce an intervention aimed at reducing the level of Competitiveness and increasing the level of Cohesiveness in her classroom.

4. **Intervention**. The teacher introduced an intervention over a period of approximately two months in an attempt to change the classroom environment. The intervention consisted of a variety of strategies, some of which originated during meetings between teachers, and others of which were suggested by examining ideas contained in individual MCI items. The strategies used to reduce Competitiveness and enhance classroom Cohesiveness involved the teacher in talking privately to students with problems, avoiding criticism of students in front of their peers, and generally being more sympathetic and helpful to students. As well, the teacher tried to encourage the class as a whole to adopt a more positive attitude towards their fellow students, especially those who were experiencing difficulties.

5. **Reassessment**. The actual form of the questionnaire was readministered at the end of the intervention to see whether students were perceiving their classroom environments differently from before. Again, questionnaires were hand scored and mean scores were graphed to form the posttest profile included in Figure 2.

The results in Figure 2 include a dotted line to indicate the class mean score for students' perceptions of actual environment on each of the MCI's five scales at the time of posttesting. Figure 2 clearly shows that some change in actual environment occurred during the time of the intervention on all five dimensions of the MCI. Comparison of the dotted line (posttest actual scores) with the unbroken line (pretest actual scores) indicates that, after the intervention, students perceived somewhat more Satisfaction, less Friction, less Competitiveness, less Difficulty and more Cohesiveness. Differences between pretest and posttest were appreciable for Competitiveness and Cohesiveness. In fact, the change was 1.3 raw score points for Competitiveness (about one standard deviation for class means) and was 2.1 raw score points for Cohesiveness (about two standard deviations). Moreover, when tests of statistical significance were performed, it was found that pretest-posttest differences were significant only for Competitiveness and Cohesiveness. These findings are especially noteworthy because the two dimensions on which appreciable changes were recorded were those, and only those, on which the teacher had attempted to promote change.

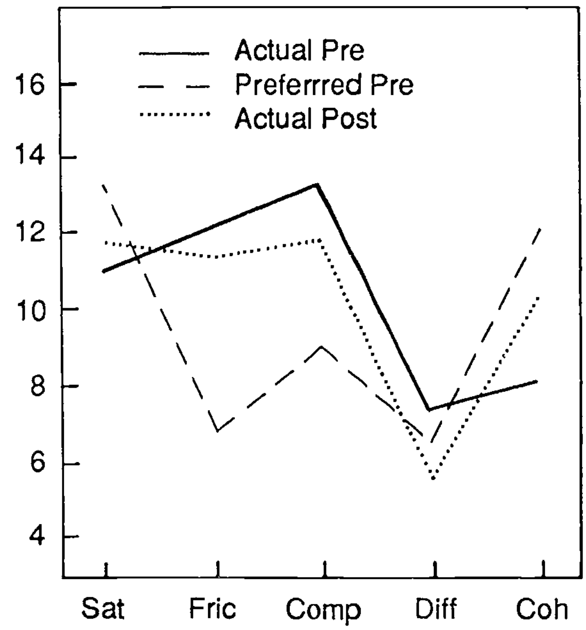

FIGURE 2. Profiles of Mean Classroom Environment Scores

Although the second administration of the environment scales marked the end of this teacher's formal attempt at changing her classroom environment, it might have been thought of as simply the beginning of another cycle. That is, the five steps could be repeated cyclically one or more times until changes in classroom environment reached the desired levels.

CONCLUSION

This chapter describes a method for assessing classroom environment and using these assessments as a basis for improving classroom environment. This approach to improving classrooms, which is based on information about student perceptions of their actual and preferred environment, is illustrated by reporting a case study of a successful application of these techniques. The promising findings from this case study and others are that, first, the assessment method was found to be reliable and very convenient, and, second, that appreciable changes in environment were perceived for those dimensions, and only those dimensions, for which improvement had been attempted by the teacher.

A major purpose of this chapter is to encourage science and mathematics teachers to assess the environments of their own classrooms. Because classroom environment instruments can provide meaningful information about classrooms and a tangible basis to guide improvements, an economical, easily-administered, hand-scorable questionnaire is provided as part of this publication. Hopefully science and mathematics teachers will make use of this classroom environment instrument in evaluating new curricula or teaching methods, checking whether the same classroom is seen differently by students of different genders, abilities or ethnic backgrounds, etc.

REFERENCES

Fraser, B. J. (1981). Using environmental assessments to make better classrooms. *Journal of Curriculum Studies, 13*, 131-144.

Fraser, B. J. (1986). *Classroom environment.* London, England: Croom Helm.

Fraser, B. J. (1989). Twenty years of classroom climate work: Progress and prospect. *Journal of Curriculum Studies, 21*, 307-327.

Fraser, B. J. (in press). Classroom and school climate. In D. Gabel (Ed.), *Handbook of research on science teaching and learning*. New York: Macmillan.

Fraser, B. J., & Fisher, D. L. (1983). Development and validation of short forms of some instruments measuring student perceptions of actual and preferred classroom learning environment. *Science Education, 67*, 115-131.

Fraser, B. J., & Fisher, D. L. (1986). Using short forms of classroom climate instruments to assess and improve classroom psychosocial environment. *Journal of Research in Science Teaching, 23*, 387-413.

Fraser, B., Malone, J., & Neale, J. (1989). Assessing and improving the psychosocial environment of mathematics classrooms. *Journal of Research in Mathematics Education, 20*, 191-201.

Fraser, B. J., & O'Brien, P. (1985). Student and teacher perceptions of the environment of elementary-school classrooms. *Elementary School Journal, 85*, 567-580.

Fraser, B. J., & Walberg, H. J. (Eds.). (1991). *Educational environments: Evaluation, antecedents and consequences.* Oxford, England: Pergamon Press.

SUPPLEMENT A

MY CLASS INVENTORY

Student Actual Short Form

Directions

This is not a test. The questions are to find out what your class is **actually like**.

Each sentence is meant to describe what your actual classroom is like. Draw a circle around

YES if you AGREE with the sentence
NO if you DON'T AGREE with the sentence.

EXAMPLE
27. Most pupils in our class are good friends.

If you **agree** that most pupils in the class actually are good friends, circle the **Yes** like this: (Yes) No
If you **don't agree** that most pupils in the class actually are good friends, circle the **No** like this: Yes (No)

Please answer all questions. If you change your mind about an answer, just cross it out and circle the new answer. Don't forget to write your name and other details below.

NAME __________ SCHOOL __________ CLASS ______

	*Remember you are describing your **actual** classroom*	Circle Your Answer	For Teacher's Use
1.	The pupils enjoy their schoolwork in my class.	Yes No	___
2.	Pupils always are fighting with each other.	Yes No	___
3.	Pupils often race to see who can finish first.	Yes No	___
4.	In my class the work is hard to do.	Yes No	___
5.	In my class everybody is my friend.	Yes No	___
6.	Some pupils are not happy in my class.	Yes No	R ___
7.	Some pupils in my class are mean.	Yes No	___
8.	Most pupils want their work to be better than their friend's work.	Yes No	___
9.	Most pupils can do their schoolwork without help.	Yes No	R ___
10.	Some pupils in my class are not my friends.	Yes No	R ___
11.	Pupils seem to like my class.	Yes No	___
12.	Many pupils in my class like to fight.	Yes No	___
13.	Some pupils feel bad when they don't do as well as the others.	Yes No	___
14.	Only the smart pupils can do their work.	Yes No	___
15.	All pupils in my class are close friends.	Yes No	___
16.	Some pupils don't like my class.	Yes No	R ___
17.	Certain pupils always want to have their own way.	Yes No	___
18.	Some pupils always try to do their work better than the others.	Yes No	___
19.	Schoolwork is hard to do.	Yes No	___
20.	All pupils in my class like one another.	Yes No	___
21.	My class is fun.	Yes No	___
22.	Pupils in my class fight a lot.	Yes No	___
23.	A few pupils in my class want to be first all of the time.	Yes No	___
24.	Most pupils in my class know how to do their work.	Yes No	R ___
25.	Pupils in my class like each other as friends.	Yes No	___

For Teacher's Use Only: S ____ F ____ Cm ____ D ____ Ch ____

This page is a supplement to a publication entitled *Assessing and Improving Classroom Environment* authored by Barry J. Fraser and published by the national Key Centre for School Science and Mathematics at Curtin University.

SUPPLEMENT B

MY CLASS INVENTORY

Student Preferred Short Form

Directions

This is not a test. The questions are to find out what you would **like or prefer** your class to be like.

Each sentence is meant to describe what your preferred class is like. Draw a circle around

YES if you AGREE with the sentence
NO if you DON'T AGREE with the sentence.

> EXAMPLE
> 27. Most pupils in our class would be good friends.
>
> If you **agree** that you'd prefer that most pupils in the class would be good friends, circle the **Yes** like this: (Yes) No
>
> If you **don't agree** that you would prefer that most pupils in the class would be good friends, circle the **No** like this: Yes (No)

Please answer all questions. If you change your mind about an answer, just cross it out and circle the new answer.
Don't forget to write your name and other details below.

NAME ______________________ SCHOOL ______________________ CLASS ______

	*Remember you are describing your **preferred** classroom*	Circle Your Answer	For Teacher's Use
1.	The pupils would enjoy their schoolwork in my class.	Yes No	___
2.	Pupils always would be fighting with each other.	Yes No	___
3.	Pupils often would race to see who can finish first.	Yes No	___
4.	In my class the work would be hard to do.	Yes No	___
5.	In my class everybody would be my friend.	Yes No	___
6.	Some pupils wouldn't be happy in my class.	Yes No	R ___
7.	Some pupils in my class would be mean.	Yes No	___
8.	Most pupils would want their work to be better than their friend's work.	Yes No	___
9.	Most pupils would be able to do their schoolwork without help.	Yes No	R ___
10.	Some pupils in my class would not be my friends.	Yes No	R ___
11.	Pupils would seem to like my class.	Yes No	___
12.	Many pupils in my class would like to fight.	Yes No	___
13.	Some pupils would feel bad when they didn't do as well as the others.	Yes No	___
14.	Only the smart pupils would be able to do their work.	Yes No	___
15.	All pupils in my class would be close friends.	Yes No	___
16.	Some pupils wouldn't like my class.	Yes No	R ___
17.	Certain pupils always would want to have their own way.	Yes No	___
18.	Some pupils always would try to do their work better than the others.	Yes No	___
19.	Schoolwork would be hard to do.	Yes No	___
20.	All pupils in my class would like one another.	Yes No	___
21.	My class would be fun.	Yes No	___
22.	Pupils in my class would fight a lot.	Yes No	___
23.	A few pupils in my class would want to be first all of the time.	Yes No	___
24.	Most pupils in my class would know how to do their work.	Yes No	R ___
25.	Pupils in my class would like each other as friends.	Yes No	___

For Teacher's Use Only: S _____ F _____ Cm _____ D _____ Ch _____

This page is a supplement to a publication entitled *Assessing and Improving Classroom Environment* authored by Barry J. Fraser and published by the national Key Centre for School Science and Mathematics at Curtin University.

Chapter 3

SCIENTIFIC DIAGRAMS: HOW WELL CAN STUDENTS READ THEM?

Richard K. Lowe
Curtin University of Technology, Western Australia

Textbooks always have played an important part in learning science. We know, for example, that one of the reasons why some students are less successful learners than others is that they have trouble reading their textbooks. In recent years, textbooks have changed a lot. The most striking change is today's emphasis on *visual* learning, shown by the relatively large number of pictures and diagrams used. While some of these, no doubt, are intended merely to attract the attention and interest of students, there seems to be a common view that diagrams make learning more effective.

But are diagrams necessarily helpful to students, or can they actually introduce another kind of reading problem? To answer this type of question, we need to know more about what does (and does not) go on in the minds of students when they encounter diagrams during science instruction. The studies described in this publication involved how people think about diagrams, and suggest how best to use diagrams to help students learn science.

Recently, we have begun to develop a much better understanding of the skills that students need to read textbooks effectively. As a result, we now know some of the main reasons why students have trouble with the *written language* in science textbooks. However, little is known about the skills needed for students to gain maximum benefit from the many *diagrams* that these textbooks contain. My research suggests that the 'reading' of scientific diagrams is itself a demanding task that should not be taken lightly.

However, this view doesn't seem to be widely held, if modern science textbooks and instructional practices are anything to judge by. The view that "A picture is worth a thousand words" often appears to be accepted unquestioningly by textbook authors and publishers. It seems that scientific diagrams are simply seen as an effective way of clarifying the subject matter. Any potential barriers to science learning that diagrams might pose generally are not considered. In general, because we live in a world dominated by visual media, the issue of whether the information in one type of pictorial material (such as scientific diagrams) might be much less accessible to the untrained eye than information in other types receives little attention. All 'pictures' tend to be lumped together somewhat indiscriminately by producers of educational resources and treated as if they are 'a powerful instructional alternative' to textual presentation.

The general purpose of the studies discussed here was to question the assumption that diagrams necessarily help students to learn science. More specifically, the aim was to find some clues as to what might be in the mind of a beginning science student when s/he interacts with a diagram. At issue is whether diagrams themselves pose special interpretative challenges over and above the challenges posed by the scientific subject matter which they are depicting. If they do pose special challenges, it would be important to know if there are particular types of knowledge and skills that might be required for effective use of diagrams in science learning.

If effective use of scientific diagrams does require special knowledge and skills, we might expect to find that students with different levels of expertise will treat diagrams in different ways when they encounter them. One way to explore this possibility is to compare the thinking of people who are highly experienced in working with diagrams with that of those who have little or no experience in this area.

Two studies of this type are reported here. In the first, the way that a group of Year 8 students (beginning their high school science studies) interacts with a particular diagram is compared with the way that a group of university science graduates interacts with the same diagram. The second study compares the way in which professional scientists think about diagrams with the way in which adult non-scientists think about them.

FIRST STUDY

Lowe (1987) explored the way in which a particular scientific diagram was perceived by two groups of students who differed in their levels of general experience with scientific diagrams. Thirty-eight university students who had just completed at least three years of science study at tertiary level made up the experienced group. Forty-eight Year 8 students with only six months of formal science instruction made up the inexperienced group. This inexperienced group had been studying air pressure and had been taught the role of aerofoils in flight during a previous lesson.

Each student was asked to write comprehensive explanations for each of six individual components of a diagram that was intended to show how the shape of an aircraft's wings helps it to fly (Figure 1). The identity of the six components had been established previously from the way in which experienced science teachers had divided up the original, complete diagram into segments when asked to identify its main parts. In addition to a segmented version of the diagram, subjects were supplied with a copy of the original whole diagram which had a descriptive caption but no labels.

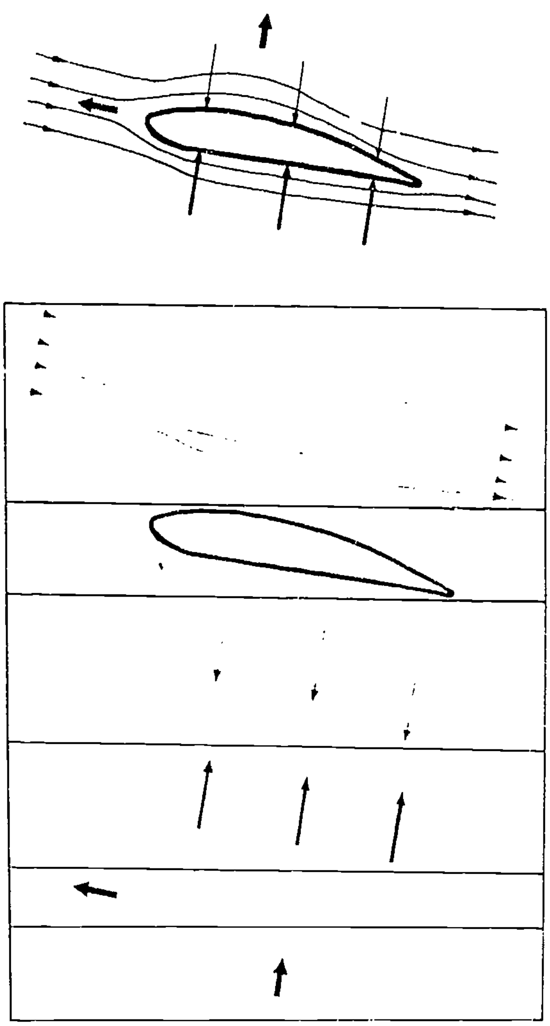

FIGURE 1. Diagram and Components

The Findings

It seems that the experienced science students 'saw' the diagram in a different sort of way from the inexperienced students. It was as if the various pieces that made up the diagram held different meanings for the two groups. The differences in their comments cannot be explained adequately simply by assuming that the experienced students just knew more about the topic that provided the subject matter for the diagram. Rather, the experienced group had a much more sophisticated approach to the diagram itself than did the inexperienced group. Central to this difference in approach were the *knowledge-based* comments that the two groups gave about the diagram. The groups not only emphasised different *types* of knowledge, but they also appeared to have knowledge *organised* differently in their minds.

Degree of Abstraction

The explanations suggested the existence of big differences between the groups in the *degree of abstraction* which they used when thinking about this diagram. The inexperienced group tended to think about the diagram in terms of their concrete everyday experience, whereas the experienced group used a more abstract scientific framework. For example, despite four weeks of prior instruction on the topic of air pressure, the Year 8 students tended not to explain the subject matter of the diagram in terms of air as a distinct scientific idea. Rather, they tended to explain diagram elements in terms of their more tangible and familiar everyday experiences. For example, the flow lines in the diagram would be referred to as 'wind' rather than as an 'air stream'.

In addition, the inexperienced group tended to refer to constituents of the diagram in a more literal manner than did the experienced group. For example, they made frequent reference to 'lines' and 'arrows' whereas the experienced subjects tended to refer to what was meant to be *represented* by these marks on the page ('air-flow', 'pressure').

It seems that the experienced group dealt with the underlying scientific ideas in the diagram while those in the inexperienced group adopted a more superficial and less sophisticated approach.

Conventions and Relationships

There were other ways in which the comments of those in the experienced group reflected a more sophisticated approach to the diagram. One type of comment suggests that they paid more attention to the *conventions* used in the diagram than did the inexperienced group. A common convention in scientific diagrams is to use non-realistic views of the subject matter in order to depict aspects that are not readily observable in more realistic illustrations.

Cross-sectional views are used widely for this purpose. Those in the experienced group were much more likely to comment on the fact that the diagram was a cross-sectional view. They also made more comments about other conventions, such as the use of arrow thickness to signify the magnitude of a force. This regard for diagrammatic conventions is of course essential for an appropriate and comprehensive interpretation of what is depicted.

Another example of the experienced group's more sophisticated approach is illustrated by comments on the wing's shape. Comments such as "the top of the wing is more curved than the bottom of the wing" contain clear references to *relationships* present in the diagram. As well as considering relationships like this that were *within* individual diagram segments, comments also were made such as "the pressure on the bottom of the wing is greater than on the top". This example shows that relationships *across* several diagram segments also were considered. This suggests that attention was given to relationships over the diagram as a whole. In contrast, few such relationships were reflected in the comments of the inexperienced students who generally used a more fragmented approach.

SECOND STUDY

Lowe (1989) sought more detailed information about the way in which experience and expertise in working with a particular type of diagram can influence the approach used in diagram-processing tasks. The processing approaches of a group of professional meteorologists and a group of adult non-meteorologists were compared as they performed a task involving a weather map. Participants were asked to reconstruct the total set of meteorological markings of a hidden weather map after only one third of these markings had been revealed to them. The areas of the map in which markings were to be revealed were chosen by each subject (Figure 2).

The procedure began by providing participants with a blank map of Australia divided into a grid of 30 squares From this map, the participant chose 10 squares, one at a time, which were to have their markings revealed. Once the markings on 10 squares had been revealed, the person was asked to complete the markings on the map.

Meteorologists

The meteorologists dealt with the map task in a manner that indicated a sophisticated and abstract view of this type of display. On one hand, they were able to 'see past' the conventional representations used as markings on the map and interpret them in terms of the real world. As the following extract shows, this meant that when necessary, they could think about the map in terms of the physical realities of a region's geography and weather:

> ... (T)his suggests it would be quite a hot day in the West because it's a summer pattern, north easterly winds, the high in the Bight, overland trajectory ...

On the other hand, however, they were also very skilled at dealing with these conventional representations in powerful ways at a very abstract level, as shown by the next extract:

> The north-west/south-east orientation of the isobar ... indicates that we have got a trough tied in with the high there.

This is something like the way in which a physics teacher can interpret a physics problem either in terms of its everyday reality or in terms of abstract principles of physics. It seems that the

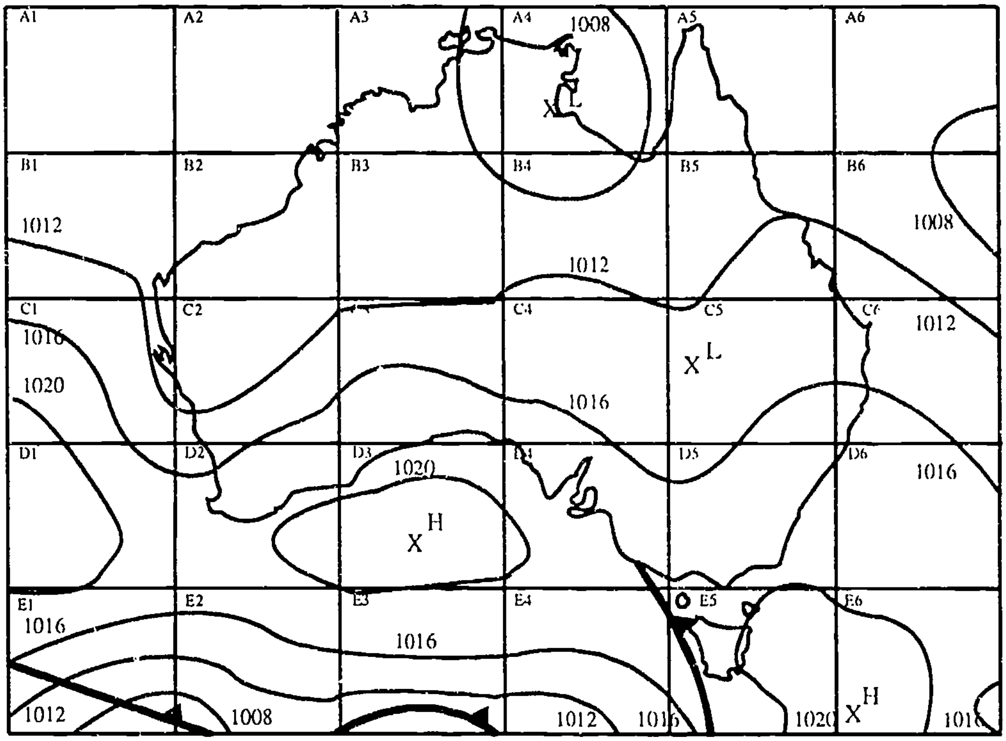

FIGURE 2: Weather Map (To Be Reconstructed by Participants)

meteorologists' natural mode of thinking about the map was at this abstract level rather than at the level of marks on the page.

The patterns of square selection and the accompanying verbalisations suggested that the meteorologists had a clear idea of where key information was likely to be found on the map. They appeared to be using knowledge of various types of *relationships* between meteorological markings that comprise weather maps. Rather than working on the basis of individual markings, they tended to treat these marks as part of larger groups or 'chunks' that encompassed several markings. For example, they grouped together a number of otherwise discrete open isobars because of a trough or ridge pattern that ran across them. It also appeared that their knowledge of the way in which information is typically organised on weather maps was coherently structured across a number of hierarchically arranged levels. At one extreme, for example, they broadly divided all weather maps into Summer, Winter or Transitional maps. At the opposite extreme, they considered small irregularities in the path of a tiny isobar fragment as indicating a local geographic effect specific to a particular region and set of conditions. Their well-structured knowledge base seemed to guide their choice of information to be revealed and their later operations in completing the map from partial information.

Non-Meteorologists

In contrast, the behaviour of the non-meteorologists suggested that they had little idea of what were likely to be important and unimportant areas of the map. In addition, they tended to work only at the level of individual markings with no apparent higher-level conceptual knowledge guiding their exploration of the map. There appeared to be no awareness of organisational principles that might specify relations between these markings and allow them to be grouped into meaningful chunks. Their choice of squares to be revealed was generally poor compared with that of the meteorologists because they tended to miss key information that would have provided a basis for useful inferences about the remaining markings on the map. Even when they did stumble across information considered highly useful by the meteorologists, they were unable to appreciate its significance and use it to advantage.

CONCLUSIONS AND IMPLICATIONS

The two studies described here sound a note of caution for those who are tempted to assume that scientific diagrams have some sort of privileged status in terms of their effectiveness as tools for science instruction. Just as there is a difference between reading scientific text and 'everyday text', there also could be a difference between reading scientific diagrams and 'everyday pictures'. Although the results discussed are necessarily quite limited in their scope, they do suggest that reading diagrams effectively is not as straightforward as often has been assumed. Hence, it should not be taken for granted that all students have the knowledge and skills required for effective reading of diagrams.

People with different levels of experience and expertise with the types of scientific diagrams examined in these studies appear to treat the diagrams quite differently. In general, the results of these studies suggest that these differences involve (a) the degree of abstraction with which the diagram is treated, (b) the extent to which the diagram is seen in terms of relationships and (c) the fluency with which diagram conventions can be handled during the 'reading' process. If similar results occur for other kinds of diagrams, perhaps we will need to give more thought to the use of diagrams in science education.

For example, we might need to teach students how to interpret diagrams rather than assume that they already are able to do this. Rather than seeing diagrams as unproblematic aids to better science learning, it could prove useful to give much greater emphasis to the development of diagram-processing knowledge and skills than is currently the case. Instead of being seen merely as an adjunct to science learning, scientific diagrams would form an object of study in themselves. However, before such a change in approach is warranted, a much clearer and more complete understanding of the processes involved in effective diagram reading would be required. The results presented here suggest that this is an important and rich area for further research.

From the results above, there follow some implications for classroom science teachers. It seems that we should not automatically expect students to gain the same things that we do from a given diagram. The skills that children have developed for the interpretation of everyday pictures are not necessarily sufficient or appropriate for the interpretation of scientific diagrams. As a consequence, we might need to include explicit instruction in diagram-processing skills as a normal part of the science curriculum. We cannot assume that all students will pick up such skills incidentally any more than they would pick up other science skills. It is especially important that we question the widely held assumption that, for lower-achieving students, diagrams provide a more accessible alternative to text. Diagram processing often requires a degree of sophistication and skill that is similar to that required to process text and therefore might not necessarily be any better developed in lower-achieving students than is text processing.

What suggestions can we make from the studies described here concerning how classroom teachers might help students make more effective use of diagrams in their science learning? Initially, it seems important to help students to develop a good working knowledge of the more common conventions found in scientific diagrams. While science teachers take for granted that explicit teaching of diagram vocabulary and syntax is necessary for certain 'special' types of diagrams, such as electronic circuit diagrams, this is not usually their approach with many other forms of scientific diagrams. However, many of the characteristics of these other more 'normal' forms of diagram also can be 'special' as far as beginning science students are concerned. Students need to see that there can be a great range of possible meanings for a particular diagrammatic symbol and that its intended meaning in a specific diagram is heavily dependent on the context. The varied uses of arrows in diagrams provides a good illustration of this point.

As well as understanding that a variety of special meanings are possible for the symbols found in diagrams, students also should be encouraged to look for patterns of organisation (relationships) amongst symbols. The capacity to group the symbols that make up a diagram into meaningful chunks at various levels seems to be characteristic of people who are skilled in diagram processing. By showing students the ways in which the numerous individual symbols found in a diagram can be related and so treated as larger groups, understanding of the major scientific ideas in the diagram can be developed. In contrast, a student who sees a particular diagram only in terms of a collection of unrelated individual elements would be unlikely to grasp the author's intentions fully. Teachers themselves know a great deal about the way that information within diagrams 'hangs together'; however, they do not always make this knowledge explicit to their students. More attention to helping students form meaningful chunks of information from the material in a diagram could benefit students in terms of both understanding and recall.

There is a variety of ways in which the knowledge and skills described here could be developed in the science classroom. Some specific teaching activities designed for this purpose are described in a number of recent articles (Lowe, 1986, 1988). Although these activities are based upon several specific diagrams, the principles which they embody easily could be transferred to other types of diagrams. By directing more attention to the way in which students interact with diagrams, science teachers have the opportunity to make much more effective use of these potentially powerful components of science instruction.

REFERENCES

Lowe, R. K. (1986). The scientific diagram: Is it worth a thousand words? *Australian Science Teachers' Journal, 32*(3), 7-13.

Lowe, R. K. (1987). Mental representation and diagram interpretation. *Australian Educational Researcher, 15*(1), 37-50.

Lowe, R. K. (1988). Drawing comparisons: School science and professional science. *Australian Science Teachers' Journal, 33*(4), 32-38.

Lowe, R. K. (1989). Search strategies and inference in the exploration of scientific diagrams. *Educational Psychology, 9*(1), 27-44.

Chapter :

IMAGES OF SCIENTISTS: GENDER ISSUES IN SCIENCE CLASSROOMS

Jane Butler Kahle
Miami University, United States of America

The scientist is a brain. He spends his days indoors, sitting in a laboratory. He is so involved in his work that he doesn't know what is going on in the world. He has no other interests and neglects his body for his mind. He can only talk, eat breathe, and sleep science.... He works for long hours in the laboratory, sometimes day and night, going without food and sleep.
(Composite statement of USA high school students, Mead & Métraux, 1957)

A scientist's totally involved in work. Therefore, they don't care about appearance. [They] wear white coats, have beards – 'cause they're men. They just seem to care only about their science work. ... They don't care about meals. Somedays they starve themselves. They walk around with their science brain all day, and they've got their laboratories.
(Interview with an Australian secondary student, Kahle, 1987a)

The above comments, collected approximately 30 years apart, paint a vivid, negative image of the scientist which has been remarkably stable over time. Why is that image so stable? What can we do to change it?

YESTERDAY'S IMAGE

Over 30 years ago, the Board of Directors of the American Association for the Advancement of Science (AAAS) decided to investigate the "great disparity between the large amount of effort and money being devoted to interesting young people in careers as scientists or engineers and the small amount of information we have on the attitudes that those young people hold toward science and scientists" (Mead & Métraux, 1957, p. 384). It commissioned a well-known scientist, Margaret Mead, and her colleague, Rhoda Métraux, to investigate the attitudes towards scientists held by high school students. Students were asked to respond to an open-ended statement which probed their *impersonal* and *personal* image of a scientist.

The responses of 35 000 students produced a dichotomy. Although students' impersonal images of scientists were very positive, their personal perceptions were negative. That is, students described scientists in general as people who were responsible for progress, who improved the quality of life and who improved the health of the population. But, when the question concerned science as a career choice for themselves or for their spouse, the responses were overwhelmingly negative.

Unfortunately, students' opinions about scientists have changed little in 30 years. A stereotypic image of a scientist has persisted in spite of the sexual revolution of the 1960s, the women's liberation movement of the 1970s and the equal opportunity legislation of the 1980s. What does research indicate about the basis of that image? How can teachers change children's images of science and scientists? Is it worthwhile to focus on that issue in a busy school day?

TODAY'S IMAGE : THE DRAW-A-SCIENTIST TEST

What image do children hold of science and scientists in the 1980s? Is it persistent across countries, or are there important or subtle differences? How do children form an image of a scientist?

Teachers and researchers have sought simple, reliable ways to assess students' images of science and scientists. Because Mead and Métraux's study showed a dichotomy between impersonal and personal images of scientists, researchers have focused on the personal image, hoping to gain understanding of students' negative attitudes about science and about becoming a scientist. Therefore, researchers have asked students to respond to scales concerning their attitudes to science and scientists and to paint a visual or verbal picture of a scientist.

In 1983, Chambers described a simple, quick and easily scored instrument, the *Draw-A-Scientist Test (DAST)*. Very simply, he asked students to draw a scientist and then coded the number of indicators which suggested a stereotypic image. Those indicators are listed in Figure 1.

Lab coat (usually but not necessarily white)

Glasses

Facial hair

Symbols of research (scientific instruments or laboratory equipment of any kind)

Symbols of knowledge (principally books and filing cabinets)

Technology: the 'products' of science

Relevant captions: formulae, taxonomic classification, the 'eureka' syndrome, etc.

From Chambers (1983)

FIGURE 1. Indicators Used to Determine Stereotypic Images of Scientists

Over an 11-year period, Chambers analysed drawings from over 4 800 children in Canada, Australia and the USA. Chambers (1983), Schibeci and Sorensen (1983), Schibeci (1986) and Maoldomhnaigh and Hunt (1988) have assessed primary school children's images of scientists with DAST. Recently, DAST has been used with secondary school students and with teacher trainees (Kahle, 1987b). Because DAST requires no reading or writing, it minimises the possibility of 'socially desirable' responses. However, with older students, care should be taken to ensure that it is presented as a serious, not frivolous, activity. In addition to the standard indicators used earlier, our research involves examining DAST drawings in terms of the sex of the scientist in the drawing in order to assess any sex-role stereotyping of science and scientists. Also, students are asked to indicate whether they are males or females in order to assess differences between boys' and girls' images of scientists.

Drawing by 15-Year-Old Australian Male Student

Figure 2 provides a summary of the results for DAST drawings done by secondary students in both Australia and the USA. The similarities are surprising. Most drawings include several of the stereotypic indicators. For example, 90% of scientists in the USA and 47% of scientists in Australia are drawn wearing a lab coat. Nearly

80% of Australian and American students envisage scientists wearing glasses. Over 90% of Australian students and 75% of American students draw male scientists, while the remaining students draw either female scientists or 'sexless' scientists (i.e., no sex identity is evident in the drawing). In both Australia and the USA, around 40% of students draw scientists with facial hair.

DAST provides an easy way to assess if students hold stereotypic (and often negative) images of scientists. For example, while scoring drawings, coders have noted that many drawings depicted eccentric or sinister people (Mason, Kahle & Gardner, 1989). Definitions were formed and drawings from several countries were recoded to identify personality types. Scientists' drawings were considered sinister if they included violent explosions, evil facial expressions, Frankenstein-type characters, etc., and eccentric if they included wild hair, unfashionable clothes, unkept appearance, bloodshot eyes, blemished complexions, etc. The sample consisted of a total of 682 students, with 548 from the USA, 110 from Australia, 16 from Norway and eight from New Zealand.

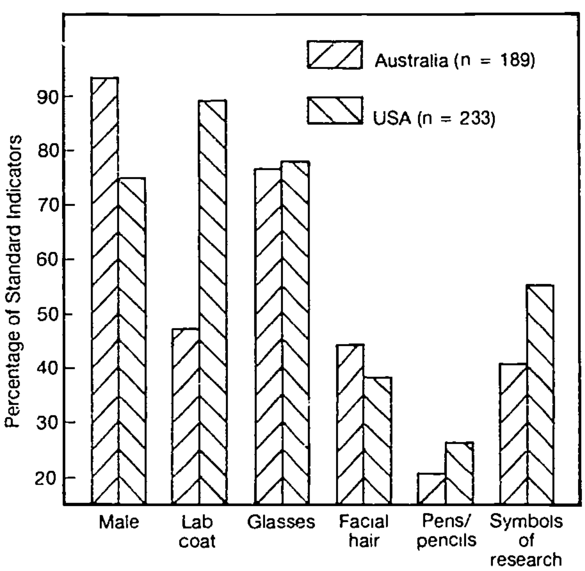

FIGURE 2: Percentage of Standard Indicators for Secondary Students' DAST Drawings

Although international results involving personality type vary somewhat by country, the basic finding is that children in several countries, including Australia, view science as harmful or evil and view scientists as eccentric or sinister men. For example, 8% of Australian students and 15% of students in the sample overall drew scientists classified as sinister. As many as 78% of Australian students and 62% of the sample overall drew scientists who looked eccentric. Our analysis of thousands of drawings paints the following picture:

> A scientist is a white male, who wears a lab coat with a pocket full of pens and pencils. He's middle aged and is either bald or has wild hair framing his myopic eyes. Comments on drawings suggest that he is antisocial or poorly adjusted, but that he is very busy with his experiments.

DAST is simple and its use is enjoyed by students and teachers. However, we must be concerned about both its *reliability* (the consistency with which test scores measure an attribute) and its *validity* (the accuracy of test scores). Researchers have established the reliability of scoring DAST by assessing the level of agreement between different people who independently code the same student drawings. They have established inter-rater reliabilities, or correlations among different people doing the coding, of 0.86 and 0.87 (Maoldomhnaigh & Hunt, 1988) and 0.97 (Mason, Kahle & Gardner, 1989).

The validity of the test, however, is another matter. Does DAST accurately reveal the images of scientists held by children? Schibeci and Sorensen (1983) suggest that interviews with students can provide an indication of the validity of DAST. When an Australian researcher interviewed Year 10 students after they drew scientists, in most cases their verbal images matched their visual ones (Tobin, Kahle & Fraser, 1990).

TRAINEE TEACHERS' IMAGES

In addition to school children around the world holding similar images of scientists, do teachers hold stereotypic images? Léonie Rennie (1986) asked Australian primary teacher trainees both to draw a scientist and to write a short verbal description of one. Their written descriptions validated their drawings. Her analysis of 79 drawings of scientists by Australian teacher trainees in their last year of preparation yielded the following picture: a white male (82%) with unruly hair (58%) who wears a lab coat (57%) and holds test tubes (56%). When Rennie tried to describe the nature of the scientists drawn, she classified 51% as looking 'somewhat unusual', 21% as appearing 'definitely crazy', 16% as looking 'puzzled' and only 12% as seeming 'ordinary'.

I replicated Rennie's study in the USA with 233 students preparing to become primary teachers and 33 students preparing to be secondary science teachers. Figure 3 shows the differences and similarities among the three groups of teacher trainees. Although slightly more women scientists were drawn in the USA samples, only women students drew them. Overall, the percentage of trainee teachers drawing male scientists was around 80% for the Australian and American samples of primary teachers and approaching 60% for the American secondary teachers.

Also, teacher trainees in Australia and the USA hold fairly stereotypic images of scientists as revealed by DAST (see Figure 3). For example, almost 60% of Australian trainee teachers drew facial hair, whereas approximately 20% to 30% of American primary and secondary trainee teachers included facial hair in their drawings. Lab coats were worn by 60% to 80% of the scientists drawn by the various samples of preservice teachers.

IMPLICATIONS: IMPROVING TOMORROW'S IMAGE

What do student drawings and descriptions tell us about their attitudes towards science? From around the world, they indicate that students from primary school through to teacher trainees hold stereotypic views of scientists. In particular, the sex of the scientist (male) can be established in a high proportion of the drawings. For example, all of the women scientists drawn in Chambers' sample, as well as all those drawn by Australian Year 10 students and teacher trainees, were done by female students. Interviews conducted with students have helped to substantiate the accuracy of the drawings. Therefore, it can be said that most students hold a masculine image of both science and scientists and that this image probably detracts from a girl's interest and self-confidence in doing science. It is to be hoped that teachers and researchers might find ways to infuse school science with an accurate and neutral image of science and scientists which appeals to a wider variety of students, both girls and boys.

Some research evidence suggests that teaching in a particular way can affect students' images of scientists. For example, after a year-long American intervention program which was designed to foster a non-masculine image of scientists, 10% of the 15-year-old boys drew women scientists, and students' depictions of female scientists involved non-stereotypic indicators, such as a neat, attractive appearance and the presence of jewellery (Kahle, 1987b).

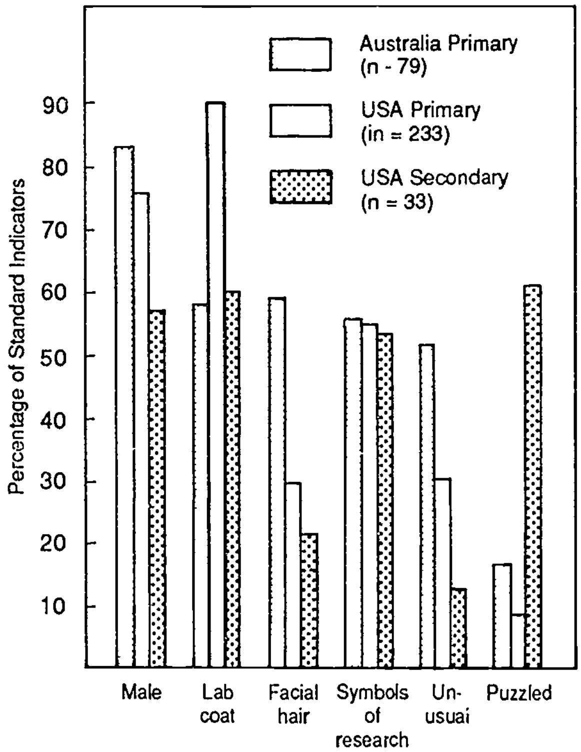

FIGURE 3. Percentage of Standard Indicators for Trainee Teachers' DAST Drawings

Also, there is a growing body of evidence that teacher behaviours and instructional strategies affect students' skills, interests and retention rates in science. This research suggests ways in which a science teacher can change tomorrow's vision of a scientist.

Research conducted in England (Smail, 1984), the USA (Kahle & Lakes, 1983), Norway (Jorde & Lea, 1987) and Australia (Parker & Rennie, 1986) shows clearly that fewer girls than boys handle science equipment, perform science experiments or participate in science-related activities in primary classrooms. The differential backgrounds that boys and girls bring to the primary school are perpetuated in them. For example, equal numbers of girls and boys might be present in science lessons, but they participate in them in unequal ways. Both primary and secondary teachers need to organise classroom activities so that girls have extra time and opportunities to do science, and so that they are expected to perform at the same level as boys.

Frequently, teachers complain that girls choose not to participate in science demonstrations and experiments. Because girls might be socialised away from science by parents and others, teachers are afraid that forcing involvement could produce increasingly negative attitudes. However, a study of USA high school teachers who were particularly successful in retaining girls in optional science classes (chemistry and physics) showed that such teachers consistently practised 'directed intervention' (i.e., girls were called upon to perform demonstrations, were selected as leaders of laboratory groups and were actively encouraged to go on out-of-school science excursions) (Kahle, 1985). Because girls' reluctance to participate could be due to a lack of self-confidence based on fewer prior experiences, directed intervention helps to equalise the equation.

Different methods and modes of teaching science can improve both the achievement levels and the attitudes of girls and boys. For example, the American study revealed that visually stimulating classrooms improved student attitudes and interest in biology (Kahle, 1985). In addition, studies in both Europe and the USA indicate that a change in mode of teaching can result in more science experiences for girls. For example, the *Girls Into Science and Technology (GIST)* project stressed the importance of including 'tinkering' activities in school science in order to overcome the lack of such experiences by girls in everyday life (Whyte, 1986). Furthermore, science lessons can provide experiences which enhance the visual-spatial abilities (e.g., mentally rotating three-dimensional figures) of all children. Because girls usually have less experience with the toys, games and activities which enhance visual-spatial ability, teachers need to incorporate such opportunities into the curriculum. Building and using laboratory equipment and models, drawing cross-sections of three-dimensional objects, and using mapping activities are examples of ways to develop visual-spatial abilities.

In addition, USA researchers have found that small-group activities and cooperative learning strategies provide a less competitive classroom atmosphere, which is preferred by most girls and by many boys. For example, Tobin (1987) reports few gender differences in teacher-student interaction patterns during individualised activities; that is, teachers are equally accessible to all students. However, during laboratory activities, gender differences can arise. Because whole-class activities, supplemented by laboratories, are the usual instructional modes, girls generally have less involvement in science classes than do boys.

Drawing by American Female Preservice Primary Teacher

Different expectations can contribute to teachers unconsciously calling more often on particular students, called 'target' students, to answer questions. Tobin (1987) reports that target students are almost always male. He and Whyte (1986) report that male students tend to dominate science classes by calling out answers, by 'hogging' the science equipment and by demanding more of the teacher's attention. The simple practice of requiring all students to raise their hands before responding to questions might lessen the number of opportunities for boys to control the class.

What can you do as a teacher? One of the possible ways for you to participate actively in changing your students' inaccurate and masculine image of science is for you to play the role of *teacher as researcher*. You could assess your students' images by using the DAST, analyse the results for your classroom and then implement some of the equitable teaching strategies suggested. In addition, you might ask your students to write a description of a scientist to complement their drawings. After a period of time, you might want to readminister DAST to ascertain whether any changes have occurred in your students' images of scientists. As a concerned teacher and as an active researcher, you could bring about change in children's images of scientists which, in turn, could affect the career choices of both girls and boys.

REFERENCES

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education, 67*, 255-265.

Jorde, D., & Lea, A. (1987). *The primary science project in Norway*. In J. B. Kahle & J.Z. Daniels (Eds.), *Proceedings of GASAT 4* (pp. 66-72). Lafayette, IN: Purdue University.

Kahle, J. B. (1985). Retention of girls in science: Case studies of secondary teachers. In J. B. Kahle (Ed.), *Women in science: A view from the field* (pp. 49-76). Philadelphia, PA: Falmer Press.

Kahle, J. B. (1987a). Images of science: The physicist and the cowboy. In B. J. Fraser & G. J. Giddings (Eds.), *Gender issues in science education* (pp. 1-11). Perth, Western Australia: Faculty of Education, Curtin University of Technology.

Kahle, J. B. (1987b). SCORES: A project for change? *International Journal of Science Education, 9*, 325-333.

Kahle, J. B., & Lakes, M. K. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching, 20*, 131-140.

Maoldomhnaigh, K., & Hunt, A. (1988). Some factors affecting the image of the scientist drawn by older primary school pupils. *Research in Science and Technological Education, 6*, 159-166.

Mason, C., Kahle, J. B., & Gardner, A. (1989). *Draw-a-scientist test: Future implications.* Unpublished paper, Miami University, Oxford, Ohio.

Mead, M., & Métraux, R. (1957). Image of the scientist among high-school students: A pilot study. *Science, 126*, 384-390.

Parker, L. H., & Rennie, L. J. (1986). Sex-stereotyped attitudes about science: Can they be changed? *European Journal of Science Education, 8*, 173-183.

Rennie, L. J. (1986). *The image of a scientist: Perceptions of preservice teachers.* Unpublished paper, Curtin University of Technology, Perth.

Schibeci, R. A. (1986). Images of science and scientists and science education. *Science Education, 70*, 139-149.

Schibeci, R. A., & Sorensen, I. (1983). Elementary school children's perceptions of scientists. *School Science and Mathematics, 83*, 14-20.

Smail, B. (1984). *Girl-friendly science: Avoiding sex bias in the curriculum.* London, England: Longman.

Tobin, K. (1987). Gender differences in science: They don't happen here! In B. J. Fraser & G.J. Giddings (Eds.), *Gender issues in science education* (pp. 37-45). Perth, Western Australia: Faculty of Education, Curtin University of Technology.

Tobin, K., Kahle, J. B., & Fraser, B. J. (Eds.). (1990). *Windows into science classrooms.* London, England: Falmer Press.

Whyte, J. (1986). *Girls into science and technology.* London, England: Routledge and Kegan Paul.

Chapter 5

METAPHORS AND IMAGES IN TEACHING

Kenneth Tobin
Florida State University, United States of America

Metaphors and images influence how teachers think and talk about teaching and what they do in the classroom. Teachers do what makes sense to them in the circumstances. What has worked in the past in a given context guides a teacher's selection of appropriate practices. However, decision-making often is not conscious.

Ongoing research with science and mathematics teachers (e.g., Tobin & Ulerick, 1989) suggests that the metaphors used to conceptualise particular teaching roles guide many of the practices adopted by teachers. In addition, teachers assume roles in business, social, sporting, family and political facets of their lives. Images projected in these various roles evolve over the years and become a part of a person's 'self'. As a teacher moves from one activity to another throughout the day, images which are projected consciously during one activity might be suppressed in another or might be evident, but less prominent. In other instances, a teacher consciously might project an image from another role in order to gain the respect of colleagues and students.

The purpose of this chapter is to explain how metaphors and images are associated with salient teaching roles and belief sets. Examples are drawn from an ongoing research program conducted in Australia and the United States in the past six years (e.g., Tobin & Espinet; 1989; Tobin & Gallagher, 1987; Tobin, Kahle & Fraser, 1990; Tobin & Ulerick, 1989). The following sections discuss (1) method, (2) metaphors and images in teaching, (3) teacher change, (4) what we learned from these studies and, finally, (5) some questions for the consideration of science and mathematics teachers.

METHOD

Teachers' metaphors and images were identified from verbal accounts of teaching and learning. Metaphors were obtained from teachers' responses to interview questions or from their descriptions of a recent lesson. Teachers also were invited to describe how they use images to think about teaching and how images and metaphors are related to each other. Interviews conducted after an observed lesson or in conjunction with videotaped replays of teaching are ideal sources for data on metaphors and images.

EXAMPLES OF METAPHORS AND IMAGES IN TEACHING

Gary did not have many problems with discipline in his teaching of science, even though misbehaviour of students was a widespread problem in the school in which he taught in Australia (Tobin & Gallagher, 1987). Gary, a martial arts instructor and holder of a black belt in karate, adopted a metaphor of *teacher as intimidator*. The images which he projected in his science classes frequently were carried over from his hobby as an exponent and student of martial arts. Thus, his posture, movement around the class, and intent stare at potential trouble-makers easily could have belonged in a karate contest. These images were a deterrent to most students who might have contemplated misbehaviour. Gary was not intimidated physically by students in his class and he was not prepared to accept unruly behaviour from them. Gary was an authority figure who demanded the respect of students because of his managerial style.

Jonathon, an American science teacher, used a metaphor of *teacher as preacher* to make sense of teaching (Tobin & Espinet, 1989). In his life outside the classroom, Jonathon was a preacher. As a teacher, he lectured from the front of the class and set seatwork tasks from the textbook. His lectures had many of the characteristics of a sermon, the textbook was his bible, and his role in the classroom was consistent with the roles which he fulfilled as a preacher. In the classroom, Jonathon projected an image of a preacher.

Sandra, an Australian high school science teacher (Tobin, Kahle & Fraser, 1990), allowed students to learn together in groups or to complete tasks independently. The metaphor of *teacher as resource* appeared to define Sandra's role and constrain her from behaving in certain ways. For example, few whole-class activities were conducted in 10 weeks of observation of teaching and, when they did occur, they were of short duration and were intended to clarify the schedule or provide details related to the administration of the program. Sandra was untiring in her efforts to share the teacher resource among the student consumers. To the extent that she was free to do so, Sandra responded to student needs by answering questions, providing explanations and generally assisting students to remain cognitively active. Even when Sandra visited a group, she usually interacted with two or three of the students at the table on an individual basis. Few visits to groups exceeded 30 seconds in duration.

One of the metaphors which Shirley used when she taught her primary mathematics class was *teacher as movie director* (Tobin & Jakubowski, 1992). In the previous two years, she had changed from being a traditional teacher of mathematics who relied on the textbook and focused on rote learning of facts and algorithms to get correct solutions. Now, she was a teacher who facilitated learning with understanding based on problem solving and cooperative learning, which involved students working together to arrive at consensus solutions to problems. Shirley used the director metaphor to make sense of her teaching role in a teaching and learning environment with which she had no previous experience. The director provides actors (i.e., the students) with a script, but it is left to the actors to create their own parts within the confines of the script. The actors cannot succeed unless the director provides them with a good script and guides them as they work together to create the film (i.e., learning). The director is in charge and manages the schedule. However, the quality of the film depends on the work of the actors and the director.

Diana, a primary teacher in the US, used three metaphors to describe her teaching role in different contexts (Tobin & Jakubowski, 1992). Usually, she managed her class as *a police officer*, in some circumstances she was *a mother hen*, and on other occasions she was *an entertainer*. Her mode of behaviour (i.e., the metaphor she used to make sense of what she ought to do) depended on the context in which learning was to occur. Each conceptualisation of her role as manager was associated with a discrete set of beliefs. Also, interviews indicated how Diana used imagery to establish a mind-frame in which she could explain how the teaching of a former teacher influenced her own teaching.

Is it possible that images are used metaphorically to make sense of a new role that is to be adopted by a teacher? The metaphorical use of images would by-pass the use of language and guide actions unconsciously. For example, the decision to use a police officer as a metaphor for managing a classroom probably is not done consciously. Something in the context might result in the construction of an image associated with a role which is well understood (e.g., a police officer) and provide a basis for subsequent behaviour. Basing actions on images associated with another role is analogous to using a verbal metaphor to make sense of a new concept. The interview with Diana suggested that she based her teaching on images associated with her favourite teacher. It is apparent that she did not sit down and meticulously describe in words those behaviours that she would adapt and adopt. Rather, the association appears to have been more direct, involving reconstructed images of her former teacher. Similarly, Diana's decision to be an entertainer probably is associated with images of entertainers whom she has experienced and occasions when, in other roles, she has been entertaining.

The examples provided above do suggest that metaphors and images are used to make sense of teaching roles. However, many questions remain to be answered. How might teachers use information about images, metaphors, belief sets and role conceptualisations? What metaphors influence the way in which mathematics and science are taught? In what contexts do metaphors influence classroom practices? How are teacher and student practices constrained by the use of metaphors? Would the use of alternative metaphors result in desirable changes in classroom practices? Are the metaphors and images used to make sense of the salient roles compatible with one another?

TEACHER CHANGE

The idea that metaphors could be used as a 'master switch' to change teachers' belief sets came in a study conducted in Australia (Tobin, Kahle & Fraser, 1990). One science teacher in this study, Peter, conceptualised his management role in terms of being *captain of the ship*. When the context was right, Peter became the captain of the ship and his students were regarded as the crew. How students and the teacher were expected to behave in activities was defined in terms of the metaphor which he used to understand management. The metaphor (and associated images) became a filter for formulating beliefs associated with management in the contexts in which it was considered relevant to manage the class in this way. Peter did not believe that it was always appropriate to be captain of the ship. Some contexts required different management styles. In such contexts, Peter believed that he should be *an entertainer*.

When Peter was entertaining the class, he was humorous, interactive and amenable to student noise and risque behaviour. Whole-class activities were appropriate for both metaphors. The captain of the ship gave orders and explanations to the entire crew and the entertainer performed to the whole audience. In both contexts, the teacher was in charge, just as the captain manages the ship and the entertainer manages the show.

What was so interesting in Peter's teaching was the quite distinct teaching style associated with each metaphor for managing student behaviour. As Peter switched metaphors, a great many variables changed as well. This finding suggests that teachers might be assisted to acquire new metaphors for specific teaching roles as a possible means of assisting them to improve their classroom learning environment.

Further insights into the importance of metaphors in conceptualising teaching roles were obtained in a study of Sarah in the US (Tobin & Ulerick, 1989). When the study commenced, Sarah had been teaching two classes for one semester and patterns of behaviour and interaction were well established. Sarah had major problems with classroom management. Although Sarah believed that her role as facilitator ought to have been regarded as having highest priority, her inability to manage her classes effectively necessitated that greater priority be given to her management role. The main metaphor Sarah used to conceptualise management was *teacher as comedian*. Teaching behaviours associated with the metaphor seemed to elicit aggressive student behaviour; students took advantage of Sarah, did not cooperate with her, and the learning environments in her classes were not conducive to learning.

Sarah described her role as facilitator of learning in terms of three metaphors, the *comedian*, the *miser* and the *saintly facilitator*. However, Sarah acknowledged that all three metaphors did not influence how she taught. The saintly facilitator was a role that Sarah only applied to her ideal class. When she taught, Sarah was the comedian and, when that was not successful, she became the miser. The essence of the three roles is captured in the following excerpts from Sarah's description of her facilitating roles:

> **Saintly Facilitator:** In this role, I am in the classroom to help people learn. Students are individuals and must be treated as such. I would like to work one-on-one with students more often. I imagine them inviting me into their 'personal space' as a trusted friend and guide.
>
> **Comedian:** The comedian believes that students will be captivated by charm, humour and well-organized presentations, which they will find enjoyable and easy to learn. Students might get restless in such a class, but hardly ever would be bored or rebellious.
>
> **Miser:** I am a facilitator with limits on my time and energy for the job. I will do only so much. I weigh the results against the hassle. I must place high value on my life outside the classroom to justify reducing my efforts in the classroom.

The excerpts indicate that Sarah viewed her facilitator role in terms of being a popular comedian. Although she had some beliefs based on what she had learned in her studies (i.e., the saintly facilitator), she acknowledged that these did not influence the way in which she planned and implemented the curriculum. The context was never right to be able to teach in that way. Further, she believed that she should not expend too much effort in preparing for her classes. This belief might have developed, in Sarah's view, because students were not cooperating with her and had become unteachable.

Sarah's beliefs about assessment were associated with a metaphor of rewards and punishment. She seemed to worry about assessment and focused on failure. Certainly, the students in her classes were not as successful as she wanted, and Sarah was aware of the problems associated with such a high number of failures. Sarah had problems, wanted to make changes and recognised that she needed assistance. Her journal entries and interviews indicated that she was reflecting on practice and did not like what she saw. Further, she knew that she could not solve her problems without assistance from others.

Sarah received assistance from a team of educational researchers. Discussions with team members focused on constructivism (von Glasersfeld, 1987) and Sarah's teaching was focused on students having opportunities to learn. Constructivism highlights the importance of what students know and the manner in which knowledge is constructed and applied. Knowledge does not reside outside the students. A constructivist perspective gives importance to learners observing, reflecting on their observations, collaborating with peers, negotiating meaning and arriving at consensus. The sense-making process is regarded as the vital part of learning as learners negotiate through processes such as describing, clarifying, elaborating, justifying, evaluating and conceding. Sarah embraced constructivism, which was readily incorporated into her saintly facilitator role.

Sarah decided to reconceptualise her role as manager in terms of being a *social director*. Her application of this role to teaching was metaphorical and resulted in rejection of many of her previous beliefs about managing a class. Her social director metaphor was associated with beliefs that were compatible with constructivism. According to the metaphor, the teacher invites students to the party of learning. Students decide whether to come or not, and the teacher's role is to create opportunities for learning. If students decide not to accept the invitation, the teacher has the responsibility to make the invitation more attractive. Only two rules applied: guests (i.e., students) should be courteous to their host (i.e., the teacher) and to one another; and guests should not disrupt the fun (i.e., learning) of others. Guests who violated these rules would be invited to leave the party. Student misbehaviour, which previously was widespread, almost disappeared overnight. With management less of an issue, Sarah pursued her roles as facilitator of learning and assessor of students. Numerous changes occurred in teacher and student behaviour.

Although disruptive behaviour diminished considerably, many students exhibited latent hostility. A change that produced almost immediate results grew from the suggestion that Sarah might view the role of assessment in terms of providing a window into the student's mind. An assessment would allow the teacher to see what a student knew or permit a student to show what he or she had learned. During the next day on which science was taught, there were significant changes. Over a short period of time, the learning environment improved appreciably. Sarah realised that so many students need not fail science, she changed her procedure for assigning grades, she communicated the new system to her classes, and she endeavoured to create an expectation of anticipated success in science. Students who had regarded her assessment procedures as unreasonable responded with enthusiasm to the new approach to assessment.

WHAT WE LEARNED FROM THESE STUDIES

Identification of salient teaching roles, and the metaphors used to conceptualise them, offers the possibility of changing what teachers do in the classroom. The metaphor used to make sense of a role is a master switch for associated belief sets of teachers. If a switch is thrown (i.e., the metaphor is changed), a host of changes follow (i.e., as new beliefs are considered relevant to the role) in the classroom. Reconceptualising a role in terms of a new metaphor appears to switch an entirely different set of beliefs into operation. Organising roles, metaphors and belief sets in this way highlights the importance of the teacher's framing of the context in determining whether or not particular actions are taken in the classroom.

It is possible for teachers to have a variety of context-specific conceptualisations for a given role. Whether or not specific teacher beliefs will influence classroom practices depends on the perceived relevance or utility of the role to the circumstances that apply in the classroom. The teacher's framing of the context in which learning is to occur is an important factor in determining what is done in the classroom. For example, a teacher might believe that, in certain circumstances, it is desirable to be a gardener (i.e., a teacher) nourishing the seedlings (i.e., the children). However, in the circumstances which prevail on a particular day, a teacher might decide that it is more appropriate to be a police officer.

The metaphors used to make sense of the roles and belief sets associated with particular actions are important factors that might be productive foci for reflection. Teachers can identify the salient metaphors for specific teaching roles and consider whether or not alternatives would lead to improvements in the classroom. If teachers decide to alter the metaphors which they use to understand particular roles, beliefs previously associated with the role might be perceived to be no longer relevant to that role. Beliefs consistent with the new metaphor then can be considered relevant and influence what teachers do as they plan and implement the curriculum.

The images which teachers use to conceptualise their teaching roles also are important in constraining teacher actions. If you ask a teacher about the best teacher whom they have had, they will reconstruct an image to which they can assign language. The image can be reconstructed when necessary and can guide subsequent actions. Images, however, have metaphors, beliefs and epistemologies embedded within them. Being guided by an image represents a potential explanation for teachers knowing intuitively how to act in certain situations.

QUESTIONS FOR TEACHERS TO CONSIDER

Analysing teaching and learning in terms of salient roles, metaphors, images and associated beliefs appeals as a basis for changing your own teaching. Relevant questions include:

- What are the most salient roles that apply when you teach?
- What images and metaphors are associated with each of these roles?
- How do the images change for a given role when the context changes?
- Are the beliefs associated with each of your roles consistent with those that are associated with other roles?
- In what ways are the images and metaphors used to make sense of a specific role beneficial? Do these metaphors and images lead to situations that are sometimes problematic?
- Identify alternative metaphors and images for each of the roles that are important in your teaching. How might these metaphors and images lead to improvements in the classroom? What limitations do these metaphors and images have?
- Analyse the teaching of a colleague in terms of salient roles, metaphors, images and belief sets. Compare your self analysis with the analysis of the colleague. Discuss what you have found with your colleague.
- Analyse the metaphors and images used by students in your class as they explain the solution to a problem in mathematics or science. Try to understand how the metaphor or image assisted them to solve the problem or prevented them from obtaining a plausible solution.

The above sample questions and ideas to pursue are based on constructivism, which invites questions about the sense-making process. As mathematics and science teachers, teacher educators and researchers, we have not focused sufficiently on this important aspect of learning. Asking questions about roles, metaphors, images and belief sets has opened doors and revealed new approaches to what we do.

REFERENCES

Tobin, K., & Espinet, M. (1989). Impediments to change: An application of peer coaching in high school science. *Journal of Research in Science Teaching, 26*, 105-120.

Tobin, K., & Gallagher, J. J. (1987). What happens in high school science classrooms? *Journal of Curriculum Studies, 19*, 549-560.

Tobin, K., & Jakubowski, E. (1992). The cognitive requisites for improving the performance of elementary mathematics and science teaching. In E. W. Ross, J. W. Cornett, & G. McCutcheon (Eds.), *Teacher personal theorizing: Issues, problems, and implications* (pp. 161-178). Columbia, NY: Teachers College Press.

Tobin, K., Kahle, J. B., & Fraser, B. J. (Eds.). (1990). *Windows into science classrooms: Problems associated with higher-level cognitive learning*. London, England: Falmer Press.

Tobin, K., & Ulerick, S. J. (1989, March). *An interpretation of high school science teaching based on metaphors and beliefs for specific roles.* Paper presented at the meeting of the American Educational Research Association, San Francisco, CA.

von Glasersfeld, E. (1987). *The construction of knowledge.* Seaside, CA: Systems Inquiry Series, Intersystems Publication.

Chapter 6

GENDER EQUALITY IN SCIENCE CLASSROOMS

Svein Sjøberg
University of Oslo, Norway

The number of girls studying science and technology is low in schools, and it becomes lower as one gets higher in the education system. At every stage at which free choices are made, the proportion of girls decreases. School science and mathematics seem to function as a vaccination against interests in these areas. At the end of compulsory schooling, many girls have developed a permanent resistance to science, mathematics or technology and they are not likely to pursue further studies in these subjects. Although knowledge often evaporates quickly, what is likely to be permanent is the attitude that science is not for girls and that it has little relevance for their lives and careers.

The above description, of course, is much too simple. Many girls do like science and mathematics and choose to pursue these areas further. Also, the results vary widely from one country to another, from school to school, from one class to another and from one area of science to another.

The examples given in this chapter are based on research done in Norway, but similar results are reported also from other parts of the world. Of particular interest is the material from the international *GASAT (Gender And Science And Technology)* conferences that are held biannually.

THE SCIENCE CURRICULUM

The science curriculum is not neutral or value free. It certainly is appealing to a lot of science teachers to see their subject removed from the turmoil of politics, ethics and social issues. But, this position is untenable.

The overall aims of science as a school subject in most countries are broader than before. They aim to do more than just give the pupil an introduction to the structure of the academic disciplines as seen from the inside. Other important aims are to convey some of the processes of science, to promote critical and scientific attitudes, to deal with ethical and societal issues – in short, to develop 'scientific literacy'.

In selecting content, one implicitly is saying something about what is important and what is not. If equality between the sexes is seen as important, this is likely to influence decisions about the curriculum. If this perspective is not taken into account deliberately, curricula implicitly could favour boys. Many science teachers, educators, textbook writers, etc. are likely to be men and, unless they are explicitly aware of gender issues, they could disadvantage girls by their decisions about curriculum materials and by their teaching practice.

SEX DIFFERENCES IN EXPERIENCE

It is widely agreed that, in teaching, one should 'build on the experiences of the learner' and 'go from the concrete to the abstract'. Boys and girls, however, bring different sorts of experiences with them to the classroom. By taking some experiences for granted and as starting points, one unintentionally could favour certain groups of pupils. Science teaching builds on experiences that strongly favour boys, as the following examples illustrate.

The Norwegian version of the Second International Science Study (SISS) included a survey of children's out-of-school experiences that might be of relevance for the learning of science in schools (Sjøberg & Imsen, 1988). The pupils answering this questionnaire were representative groups aged 10-11 years (N=1 400) and 15-16 years (N=1 500). Differences between subgroups were examined according to geographical location, social background, etc. The largest differences occurred for sex.

The following pattern emerged when girls' and boys' responses were compared. Girls dominated strongly in all activities connected with the home and household. They also dominated in activities connected with biology, gardening, nature study, health and handling and caring for animals. Activities like collecting stones and taking photographs also were mainly 'girls' activities'.

Boys dominated most strongly in activities connected with cars (except for washing a car, where boys and girls were equal). These activities included charging a battery, using a jack, renewing spark plugs, etc. Boys dominated on activities related to electricity, especially in activities like attaching a lead to a plug. Smaller differences occurred for changing batteries and changing bulbs. Boys also had greater involvement in the use of a variety of mechanical tools.

Most differences in experience were dramatically larger at age 16. Whereas girls systematically scored higher on 'male' experiences as they got older, it often was the opposite with boys, whose scores on 'female' activities became lower as they got older. Compared with 11-year-olds, boys at the age of 16 years reported lower activity on most household activities and also on activities like:

- watching an egg hatch
- raising tadpoles or butterflies
- planting seeds to see them grow
- growing vegetables in a kitchen garden
- studying fossils
- making jam from wild berries
- collecting flowers for a herbarium.

Most of the 100 activities listed in the questionnaire have some relevance to science. They constitute possible starting points for school science, or they can be used as concrete examples in the treatment of science topics. If we compare the list of experiences sorted by sex differences, we immediately are struck by the fact that school science officially builds on boys' experiences much more than on girls' experiences. At least, this is the case for the traditional Norwegian curriculum, where physics has a strong position.

SEX DIFFERENCES IN INTERESTS IN SUBJECT MATTER

Sex differences in experiences also are reflected in differences in interests. The Norwegian examples below might shed light on student interests. The first three examples are reported in Lie and Sjøberg (1984) and the fourth example comes from Kjærnsli (1989).

Example 1

Five hundred pupils aged 12 and 14 years were presented with lists of topics that possibly could be covered in science lessons. Students were invited to identify the topics that appeal to them and the topics that they would like to learn more about.

Boys reported strong interest in subject matter related to cars and motors. Girls were interested in subject matter related to health, nutrition and the human body. But, the differences showed up also in the kind of *context* implied in the description of the subject matter. In general, girls were interested when the subject matter was placed in a context related to daily life or to society. Relevance was very important for girls. Girls also reported stronger interest in subject matter with aesthetic aspects (snow crystals, the rainbow) or ethical aspects.

Different key words for the 'same' subject matter gave widely differing results. Girls were interested when key words were colours, the eye, etc., while boys were interested in 'pure' physics concepts, light or optics. Girls similarly were interested in music, instruments and the ear, while boys reacted more positively to sound as a key word.

Example 2

A representative group of 300 university students were invited to identify, from a long list, which topics should be given higher priority in the school physics curriculum in order to make it more interesting. The topics that came out on top of the list were: 'how physics is used in society', 'the physics of daily life', and 'the body and the senses'. It is interesting to note that, although the female students gave a much higher rating to those topics than did male students, they also were on top of the list for male students. This suggests that a science curriculum more suited to the interests of girls need not disadvantage boys.

Example 3

More open-ended approaches to the same problem area also have been undertaken. In one investigation, 200 14-year-old pupils were invited to write a few lines in answer to the following question: "Scientists make new things or try to understand what happens in nature and with people. If you could decide, what would you ask scientists to do?"

The results indicated that the human body, health (23%) and anti-nuclear weapons (14%) were on the top of the girls' list. Boys had technology (24%) and astronomy (14%) on top of their lists. Only 9% of the boys mentioned health or the human body.

We see that the general pattern is the same as in the investigations with closed alternatives. Girls are oriented towards biology, health and the body and towards the consequences of technology.

Example 4

Ninety pupils of age 11-12 years were asked to write an essay on what they would like to do if they were scientists. In general, the girls gave more weight to biological and medical problems. They also explicitly mentioned that they wanted to help other people. This seldom was mentioned in the boys' writings. It is also noteworthy that none of the children mentioned anything related to warfare or destructive uses of science – a strong contrast with what a large proportion of 'real' scientists actually do. The same results emerged from a large essay competition for Swedish school children. It could be a good idea to inform the scientific communities about the kinds of ideals that young people have.

SEX DIFFERENCES IN JOB PRIORITIES

When pupils in the Norwegian component of the Second International Science Study were asked to rank different factors that could be important for their future choice of occupation, some striking sex differences occurred (Sjøberg & Imsen, 1988). In general, girls tended to give much higher importance to person-oriented aspects such as working with people (instead of things) and helping other people. On the other hand, boys attached more importance to getting a high salary, becoming famous, controlling other people and having time for their own interests. The gender pattern in these responses is the same for pupils at ages from 10 to 19 years.

One obvious consequence is that 'girl-friendly' science would be presented as a human activity dealing with people, and would stress that science can be used in helping people obtain a better life.

THE IMAGE OF SCIENCE AND THE SCIENTIST

Pupils gradually develop ideas about what science is 'really' all about and what scientists are like as persons. This image of science is probably more stable in children's minds than the facts and laws which they learn at school.

The image of science that is projected is mostly covert and implicit. It is a cumulative result of various influences at school, such as textbooks, teachers' behaviour and personalities (including the sex of the science teacher). Images of science also are developed throughout-of-school influences such as cartoons, fiction books, television series, mass media, news coverage, etc. In many cases, the scientist is presented as an old, absent-minded professor (always male), sealed off from the rest of the world in his laboratory, where he invents strange chemicals or bombs that could blow the whole world to pieces. The 'crazy scientist' is a nearly mythological figure, kept alive even in children's science programs on television.

Drawings and Descriptions of Scientists

In a previous issue of *What Research Says to the Science and Mathematics Teacher*, (Kahle, 1989) described the Draw-A-Scientist Test, which simply involves inviting students to draw what they think a typical scientist looks like. From these pictures emerges an image of the scientist as seen by children. In a recent Norwegian study (Kjærnsli, 1989), we found that 10- and 11-year-olds drew the typical scientist as a rather strange-looking male with spectacles, beard and a laboratory coat and surrounded by chemical test tubes, microscopes and other symbols of research. While all the boys drew a man, about a quarter of the girls drew a woman. This percentage of Norwegian girls drawing female scientists is much higher than previous studies in Australia. Another interesting difference is that Norwegian students quite frequently drew the scientist out-doors, whereas practically none of the Australian students did this.

The Typical Physicist

University students from different faculties were presented with a list of different personal traits. They were asked to indicate on a scale whether the typical physicist or physics student would possess more or less of each trait than the average person. Figure 1 summarises the 'personality profile' of the physicist as seen by these students.

Physicists are more:	Physicists are less:
Logical	Artistic
Intelligent	Interested in people
Determined	Politically engaged
Objective	Extrovert
	Imaginative
	Responsible

FIGURE 1: The Personalities of Physicists as Seen by Norwegian Students (Lie & Sjøberg, 1984)

When we compare this image of the physicist with the often documented self-concept of girls and with their important priorities for choice of occupation, we see that the image of the physicist is nearly the negation of what the average girl values.

The Humane Biologist and the Inhumane Physicist

In the Norwegian component of the Second International Science Study (Sjøberg & Imsen, 1988), students were presented with several pairs of words with opposite meaning (e.g., Good - Evil) placed on each side of a five-point scale. Students were invited to locate on this scale two typical scientists, namely, a researcher in physics or technology and a researcher in biology or medicine. The results indicated a personality profile of these categories of scientists as perceived by pupils.

The overall picture was that girls and boys differ very little in their perceptions of the typical scientists. Also students of different ages in general had a similar impression. Younger pupils held the same conceptions of scientists as 19-year-old students.

The two types of researchers were considered similar on some qualities, but different on others. Both the biologist and the physicist were considered by students to be very accurate and intelligent, with the physicist a little in front. (This was particularly the case in the eyes of girls.) Both scientists also were perceived as industrious. Both types also were viewed as rather imaginative, with the biologist seen as more imaginative than the physicist.

For the remaining qualities, the biologist was viewed more positively than the physicist. The biologist was seen as caring, while the physicist was considered as selfish. The biologist was perceived as open, but the physicist was viewed as closed. Also, the physicist was considered as boring and inartistic, while the biologist was considered to be neutral on these traits.

Altogether, the image of the physicist is far from flattering. For most girls (and certainly also for many boys!), it is expected that this image will be frightening. The physicist is seen as having a cool, rational intellect, but lacking in the warmth, care and human characteristics that we have seen are part of the girls' culture.

This image could be correct or false. But, we could have a vicious circle. That is, the image of science is likely to have a great influence on the recruitment of future scientists; and, because girls are more person-oriented, it is likely that this image will have special significance for their subject and career choices.

Persons who feel uncomfortable with the cold and intellectual image of physics are not likely to choose it as a career. Hence, if we recruit future scientists that correspond to this widespread stereotype, the hypothesis could be self-fulfilling.

SO WHAT? STRATEGIES FOR CHANGE

Necessary conditions for change include recognising that there is a problem. However, no one strategy is likely to have an immediate and measurable effect. Rather, it is likely that small changes in many areas are likely to give results. These changes could be related to the daily teaching practices of teachers, or could result from national curriculum policies, teacher preservice and inservice education, etc.

Although the perspectives developed in this publication by and large are based on results from other countries, recent Australian publications offer very practical advice for more gender-inclusive teaching (Gianello, 1988; Lewis & Davis, 1988).

What would gender inclusive science curriculum look like? First of all, it is important that one removes all kinds of sexism from curricula and textbooks. This means that illustrations and examples must show both sexes in active situations and balanced with respect to frequency of presentation. When theoretical ideas are shown in practical use, it is important to look for examples that are based on girls' experiences and appeal to their interests.

But curricular changes must go deeper than just replacing illustrations involving boys with those involving girls and trading one example with another. It is urgent to look at the organising principles of the course material, and it is important to examine the context in which the material is presented.

The same content of science might be approached from different angles. The starting point as well as the end point are important for the pupils' motivation to work with the material. Our evidence shows that organisation based on personal relevance (e.g., the physical senses and the human body, the use of science to improve life for ourselves and other people) is important, especially for girls.

Any curriculum operates in a context. Evidence suggests that this is especially important for girls. The absence of a context could lead to science being understood as something remote from real life both on the personal and the societal level. School science should be presented in the same context that 'real science' operates (i.e., as an important tool for the shaping of destinies for people and nations) and as potentially both good and evil, depending on how it is used. Therefore, examples of both positive and negative uses should be presented. The new Norwegian curriculum stresses that both science and technology are constructed by people with different interests and values. Science should be presented as a *human* activity, not merely as a pure and logical search for objective truth and eternal wisdom.

Finally, it would be an important achievement if school science could have more of the aesthetics, enjoyment and intellectual stimulation that characterises 'real science'.

The considerations above might be easier to fulfil in schools like those in Norway, where science is taught as an integrated subject, because real examples seldom follow the boundaries of scientific knowledge. But this is not an absolute requirement; there are also good examples of separate sciences based on personal relevance and social applications.

Considerations like the ones above have been the foundation of recent curriculum revisions in Norway, when equality between the sexes has been put up as one of the main aims of science education. Although it is a long way from an official curriculum to real classroom changes, a clear official stance on this issue will help.

In many countries, the educational system requires specialisation at an early age. Choices that later turn out to have important implications are made at a stage when pupils often are unaware of the consequences and are very sensitive to gender identity. These factors exert a pressure on both girls and boys to act according to traditions and to the expectations held by the girls' and boys' culture. Hence, the notion of a 'free' choice is questionable under such pressures. Empirical evidence shows that students' choices between optional subjects reinforce the traditional gender-based divisions of society.

In many countries, an accepted and officially stated aim of the school is to *counteract* choices based on gender traditions found in society. If this is to be taken seriously, it could indicate a strategy of 'forced choices', where curricular options are deliberately used to bridge the gap in experiences between girls and boys.

REFERENCES

Gianello, L. (Ed.) (1988). *Getting into gear: Gender inclusive teaching strategies in science developed by the McClintock Collective.* Canberra, Australian Capital Territory: Curriculum Development Centre.

Kahle, J. B. (1989). *Images of scientists: Gender issues in science classrooms* (What Research Says to the Science and Mathematics Teacher No. 4). Perth, Western Australia: National Key Centre for School Science and Mathematics, Curtin University of Technology.

Kjærnsli, M. (1989). *Elevers forestillinger om forskning og forskere* [Pupils' images of scientists and research]. Higher degree thesis, University of Oslo.

Lewis, S., & Davis, A. (1988). *Gender equity in mathematics and science* (GAMAST – Girls and Mathematics and Science and Technology professional development manual). Canberra, Australian Capital Territory: Curriculum Development Centre.

Lie, S., & Sjøberg, S. (1984). *Myke jenter i harde fag?* [Soft girls in hard science?]. Oslo, Norway: Universitesforlaget.

Sjøberg, S., & Imsen, G. (1988). Gender and science education. In P. Fensham (Ed.), *Development and dilemmas in science education* (pp. 119-161). London, England: Falmer Press.

NOTE

Most of the instruments used in the research reported here, together with a report with comments on the Norwegian results, are available in English translation from the author.

Chapter 7

TARGET STUDENTS

Kenneth Tobin
Florida State University, United States of America

Teaching is a very isolated profession. It is uncommon for science and mathematics teachers to observe one another teach. Also, because teachers are so busy, they might observe only a fraction of classroom events and therefore might not have a reliable picture of life in their own classrooms.

In the staffroom, it is unusual for teachers to discuss substantive issues associated with teaching and learning. In fact, the culture of schools often is not to 'talk shop' during break times. As a consequence, teachers have sketchy details of what happens in their own classrooms and those of their colleagues.

Until recently, most research has not focused on ascertaining what happens in science and mathematics classrooms. However, this question became the focus of a five-year program of research that is still ongoing (e.g., Tobin & Fraser, 1987; Tobin & Gallagher, 1987; Tobin, Kahle, & Fraser, 1990). This research focused on the manner in which students interacted with the teacher and with each another.

The first answer to our question regarding what happens in science and mathematics classes is that a high percentage of the time is allocated to two types of whole-class activities, namely, lectures and interactive activities. We also found that interactive activities were dominated by a small group of students called *target students* (i.e., students who dominate the interactions with the teacher, usually in whole-class activities). This chapter explores what we have learned about target students and the reasons why mathematics and science teachers permit a relatively small number of target students to dominate interactions involving the teacher and other resources. Three assertions derived from several studies conducted in Australia and the United States are presented and discussed below.

METHOD

Several methods were used to identify the target students in a class. First, and most obvious, was careful observation of students' participation in particular activities. Which students answer most questions? Which students ask most questions? Who raise their hands most often to answer questions? Who does the teacher call on most frequently to answer questions? Who responds to questions without being called on by the teacher? Answers to questions such as these soon revealed a pattern in most classes. The same student names seemed to emerge.

A second method of identifying target students was to ask the teacher and students questions such as those listed above. It made no difference whether the questions were asked orally or in writing. A striking similarity was observed in the list of student names provided by the teacher and students and the list of students observed by the researcher to be most involved in interactions. Initially target students were identified in whole-class discussions. However, as our studies progressed, we also observed target students in small-group discussions (i.e., students who dominate discussions) and laboratory activities (i.e., students who dominate the use of apparatus).

ASSERTION 1: TARGET STUDENTS ARE PRESENT IN MOST CLASSES

Most classes involved in our studies contained target students. For example, in four of the five science classes taught by Mr Hoskin (Tobin, Espinet, Byrd & Adams, 1988), three to five target students dominated whole-class interactions. There was a smaller number of target students in the general science class. Target students asked most of the questions and overtly responded to teaching cues more often than others in the class. Responses largely involved calling out, and hands were seldom raised. In a chemistry class taught by Mr Hoskin, 36 questions were asked in a 15-minute segment of one lesson. Nineteen questions were asked by one girl and four boys asked 19 questions. The remaining students in the class were involved in a covert manner only. Because the class consisted of 12 males and 8 females, more female target students might have been anticipated.

Although most target students were male, there were obvious exceptions. For example, Kathryn, one of the most able students in her class, dominated whole-class interactions along with four males. Furthermore, Tobin (1988) observed science classes in an all-girls school. Classes were characterised by several students who were much more dominant in classroom interactions than others (i.e., female target students).

Many teachers were unaware of the presence of target students or inequitable involvement of males and females. When informed, most teachers wanted to make some adjustments to their teaching. However, not all teachers wanted to change their practices. Perhaps the best example of a teacher who was steadfast in his beliefs about teaching was Mr Hoskin, who had won a teacher-of-the-year award in a State in the US (Tobin, Espinet, Byrd & Adams, 1988). The following excerpt from an interview suggests that Mr Hoskin had made up his mind about target students and the involvement of females in science:

> Whenever any group interaction is held, only a few people dominate the answering of questions. This is nothing new. There is nothing wrong with this. I feel that your assumption that more female target students might be expected in advanced sciences is wrong. Very few females actively participate in any higher-level mathematics or science courses. This is fact, not assumption.

Tobin, Espinet, Byrd and Adams (1988) observed target student behaviour in laboratory activities. Because of equipment limitations, it was not possible for all students to participate by doing. Consequently, the stage was set for one or two students to monopolise the use of the equipment. For the majority of the time, most students watched someone else doing the experiment. Students seemed happy with this arrangement because the desired outcome of the laboratory appeared to be the completion of the worksheets rather than learning to manipulate experimental apparatus or constructing knowledge of science.

It is possible that target students in Year 12 classes could have been target students for most of their high school lives. Tobin (1988) reported that 21 target students were identified in Year 8 science classes during the first six weeks of a study. Twelve months later, these students were in Year 9, which was streamed according to science ability. Because the 21 target students tended to be the highest-achieving students, most of them were streamed into two Year 9 classes. Only 10 of the original 21 target students continued as target students in Year 9. Therefore, ability grouping in Year 9 had allowed another set of target students to emerge in the lower-ability classes. With two exceptions, the students identified as target students in these classes were not in the list of 21 students from the previous year.

In contrast, the target students from Years 9, 10 and 11 tended to be target students in the subsequent year level as well. There were some variations which might be attributed to promotion of a target student to a higher-level class, personality clashes with a specific teacher, loss of interest in science or personal difficulties for specific students. However, approximately 90% of the target students identified in Years 10-12 were identified as target students again 12 months earlier.

Students who were target students in Year 8 and were not target students in Year 9 found science more difficult in Year 9 and more competitive. Most of these students regarded the target students in their class as bright, but disliked them for the public manner in which they flaunted their knowledge. Most target students reported that students made fun of them in and out of class. Alienation from other students could have been the root cause for these students to group together for activities such as discussion and laboratory investigations.

Tobin and Malone (1989) provide evidence that target students compete with one another during whole-class interactions. This was most evident in the types of answers provided by the more-able students. Responses to questions tended to go beyond what was required by the teacher, and terms were used that others in the class would not necessarily understand. There is a possibility that teachers encourage this kind of verbal response from target students and the observations suggest that instruction was pitched at the ability level of these students.

Target students tend to compete with one another for a variety of reasons. When they ask and answer questions, they could be trying to impress the teacher with their knowledge, impress other target students in the class, or find out whether their knowledge is complete. Undoubtedly, some of these motives apply to some target students and other motives would certainly apply as well. The members of the target student clique compete with one another, often are disliked by others in the class and serve multiple roles within the class.

From the teacher's frame of reference, target students assist in getting the work done and provide feedback that the instruction is successful. Within the target student clique, the involvement of target students helps learning because they ask the right questions and, generally speaking, provide responses to questions that clarify and elaborate understandings. From the perspective of others in the class, target student involvement might not be a help at all. The questions that they ask and the responses that they provide could be too complex for most students in the class.

In a study of mathematics teaching, one teacher did not have target students in his classes (Tobin & Malone, 1989). The teacher, Andrew, endeavoured to speak with as many students as possible during each lesson. He called on a relatively large number of students during whole-class activities and, during seatwork activities, he responded to student requests for assistance. Andrew used questions to probe student understanding of mathematics and he took the time to assist students to understand what they were doing. Because of a rule that students could not call out, the whole-class interactive activities were orderly, and the majority of students in the class raised their hands to participate. There was some incentive for students to think about teacher questions, as Andrew sometimes called on students with their hands raised and on other occasions called on students without their hands raised.

Andrew demonstrated that whole-class interactive activities could be used as a means of introducing and revising mathematics content and ascertaining the extent to which students understood the lesson content. Andrew asked questions because he wanted to know the answers and he adjusted instruction on the basis of the answers which he received. He selected a wide range of students to respond to questions because of a concern with the learning of all students in his class.

ASSERTION 2: TARGET STUDENTS TEND TO BE HIGH ACHIEVERS

There appear to be two types of target students. The first type consists of students selected by the teacher to respond to questions. These students are selected because, in the opinion of teachers, they can contribute a response to facilitate learning and content coverage. In the interviews, one teacher described these students as high achievers. Confirmation of this trend was obtained in analyses involving the science achievement and formal reasoning ability of target students. Tobin and Gallagher (1987) reported that target students attained higher science achievement scores and had higher levels of formal reasoning ability than did other students in the same class.

There was a tendency for target students to respond to high-level cognitive questions posed by the teacher. When suitable answers were received from these students, the teachers tended to paraphrase and elaborate on them. In this way, knowledge was developed from the responses of students and participants received feedback about the adequacy of their responses. However, non-target students did not receive the same amount of feedback and their concepts were not evaluated, clarified or elaborated by the teacher to an appreciable extent. Consequently, the learning environment for target students was more conducive to learning with understanding than the learning environment which applied to non-target students.

ASSERTION 3: TARGET STUDENTS TEND TO BE RISK TAKERS

A second type of target student initiated whole-class interactions by raising the hand or by calling out to respond to teacher questions, asking questions and evaluating the responses of others. Of course, the two types of target student are not mutually exclusive. A significant proportion of target students who volunteered to participate in science and mathematics activities also were called to respond as a result of teacher initiatives.

Most teachers directed a high proportion of questions to the whole class rather than to individuals. This style of questioning favoured risk takers who called out or raised their hands to volunteer an answer. Questions tended to be asked at a rapid pace and students were encouraged to raise their hands in response to teacher questions. Teachers stated that students who raised their hands were likely to be selected more often than those who did not. Although teachers endeavoured to maintain a high risk level by occasionally calling on students with their hands down, the observations indicated that the students who were most involved were those called on after raising their hands, those who called out a response to a question, and those who signalled an intention to contribute by non-verbal means.

Student interviews (Tobin & Malone, 1989) suggest that, whereas target students did not appear to be afraid to answer questions, many non-target students did not like to be wrong because of what the teacher and other students in the class might think. It was apparent that some target students had a strong orientation to accept responsibility for their own learning. As a consequence, they asked a question of the teacher if they needed to know something that had not been explained to them. These students also responded to questions if they thought that they knew the answer. In contrast, other students stated that they would only respond to questions when they were certain that they knew the answer.

Some target students used the public forum of the classroom to gain recognition rather than to learn (Tobin, 1988). For example, Spencer was a show-off and liked to ask 'off the wall' questions in order to frustrate the teacher and to inject humour into the class. At least that is how the teacher and most others in the class viewed Spencer's behaviour. This was not the way that Spencer viewed his own behaviour. Spencer said that he liked to achieve and be recognised by the teacher and other students. He liked everyone to know when he had the right answer, he always would attempt to answer questions and did not worry whether he was right or wrong. Sometimes, he raised his hand and, on other occasions, he called out. He stated that he asked a lot of questions because he wanted to find out why things happened in the way in which they did. He valued discussion as a learning mode and did not enjoy listening to teacher explanations.

The observations reveal that there are one or two 'Spencers' in most classes. These students disrupt the class with their comments and noises which are intended to be heard by others in the class. In some cases, the remarks are related to instruction. However, the tone of the response attracts attention to the respondent. The involvement of these students make classroom management very difficult for teachers. In many cases, the students involved in classroom 'banter' appear to lack motivation to learn and appear alienated from the system.

A relatively small number of students seem to seek a public forum in an endeavour to gain recognition. On occasions, these students inject humour into the lessons and, on other occasions, they are a source of disruption. These 'risk takers' had a significant influence on many of the observed lessons. Students in the class seemed to approve of the disruption and this provided encouragement to repeat the performance.

CONCLUSIONS

Ongoing studies of high school mathematics and science classes indicate that the existence of target students is widespread (e.g., Tobin, 1988). Not only are target students apparent in whole-class interactions, but they also can dominate small-group activities, interactions with the teacher during seatwork activities, and laboratory activities. However, because of the dynamic and complex nature of teaching, it is possible that the presence of target students might not be recognised by most teachers, and potential problems associated with disproportionate target student involvement might never be considered. Yet, the results of five years of research suggest that target students might exist in classes for a variety of reasons and fulfil different niches in the classroom ecosystem. Consequently, prescriptions to teachers about the need to minimise target student involvement might not be appropriate or well received. Ultimately, teachers need to decide what is and is not desirable in their own classrooms. If teachers do decide that target student involvement should be curtailed, it is likely they will need assistance to change in the manner intended. Recent studies have highlighted the value in having colleagues in the same school provide feedback about teaching, analyse what happens in lessons, and consider alternative teaching and learning strategies.

One solution to the problem of teachers being unable to identify target students is to involve teachers in conducting research in their own classrooms. That is, teachers could be involved in: formulating problems, questions and plans; data collecting, analysis and interpretation; and dissemination of the findings. The thought and reflection associated with conducting research is likely to catalyse changes in beliefs, knowledge and classroom practices.

Teacher-researchers can investigate the existence of target students, the characteristics of various types of target students, and alternative ways of engaging learners in science and mathematics classes so that target student involvement is no longer a potential learning problem. The cognition which accompanies discussions and arguments over interpretations of data are likely to drive understandings about teaching and learning to new levels. Asking questions and seeking answers can provide a context for teachers to reflect on teaching and learning practices, to analyse and discuss alternative teaching strategies, and to identify desirable changes and procedures for implementing change.

There is little doubt that target students enjoy a more favourable learning environment than their non-target peers in the same classroom. The purposes of interacting in the classroom are numerous and relate to communication and learning. For example, the teacher asks questions to ascertain whether students understand what s/he is endeavouring to communicate or to focus student thinking on some aspect of the lesson. As students respond to a teacher's question, they have an opportunity to assign language to what they have learned. Thus, students describe and elaborate their knowledge, clarify, evaluate and often restructure what they know as they respond to a question. Alternatively, a person might ask a question to seek information or to solve a puzzle in his/her mind, or make an evaluative statement about something a teacher or student has said. Thus, students who engage in verbal interactions are involved in an overt manner that has the potential to improve their learning. In contrast, those who do not engage in verbal interactions might be engaged in an active manner or, alternatively, they might not be thinking about a question or its answer. Over a period of time, students who do not engage in verbal interactions have a different type of learning environment than those who do. As a consequence, target student behaviour can promote inequitable learning experiences. Teachers should give consideration to adopting practices associated with equitable involvement patterns of students, irrespective of gender, race and socioeconomic status.

REFERENCES

Erickson, F. (1986). Qualitative methods in research on teaching. In M.C. Wittrock (Ed.), *Handbook of research on teaching* (3rd. ed.) (pp. 119-161). New York, NY: Macmillan.

Tobin, K. (1988). Target student involvement in high school science. *International Journal of Science Education, 10*, 317-330.

Tobin, K., Espinet, M., Byrd, S. E., & Adams, D. (1988). Alternative perspectives of effective science teaching. *Science Education, 72*, 433-451.

Tobin, K., & Fraser, B. J. (Eds). (1987). *Exemplary practice in science and mathematics education.* Perth, Western Australia: National Key Centre for School Science and Mathematics, Curtin University of Technology.

Tobin, K., & Gallagher, J. J. (1987). Target students in the science classroom. *Journal of Research in Science Teaching, 27*, 61-75.

Tobin, K., Kahle, J. B., & Fraser, B. J. (Eds.). (1990). *Windows into science classrooms: Problems associated with higher-level cognitive learning.* London, England: Falmer Press.

Tobin, K., & Malone, J. (1989). Differential student participation in whole-class activities. *Australian Journal of Education, 33*, 320-331.

Chapter 8

ASSESSING THE CLIMATE OF SCIENCE LABORATORY CLASSES

Barry J. Fraser and Geoffrey J. Giddings
Curtin University of Technology, Western Australia

Campbell J. McRobbie
Queensland University of Technology

Laboratory teaching is one of the unique features of education in the sciences, but there is a questioning of whether the great expense of maintaining and staffing laboratories is really justified (Hofstein & Lunetta, 1982), and whether or not many of the aims of laboratory teaching could be pursued more effectively and at less cost in non-laboratory settings (Pickering, 1980). Students' reactions to practical work often confirm the views of critics.

But, because research has not been comprehensive, we simply do not know enough about the effects of laboratory instruction upon student learning and attitudes. Consequently, it was timely to initiate the new line of research described here to help us obtain feedback about students' views of laboratory settings and to investigate the impact of laboratory classes on student outcomes.

Although classroom environment is a subtle concept, remarkable progress has been made over the last quarter of a century in conceptualising, assessing and researching it. This research has attempted to answer many questions of interest to science teachers. Does a classroom's environment affect student achievement and attitudes? Can teachers conveniently assess the climates of their own classrooms and can they change these environments? Do teachers and their students perceive the same classroom environments similarly? What is the impact of a new curriculum or teaching method on classroom environment? These questions represent the thrust of the work on classroom environments over the past 25 years (see Fraser, 1986; Fraser, 1989b; Fraser & Walberg, 1991).

Because of the importance of classroom environment, Issue 2 of *What Research Says to the Science and Mathematics Teacher* (Fraser, 1989a) was devoted to describing the *My Class Inventory* and to showing how teachers can use it to assess and improve the climate of their classrooms.

The present chapter complements the previous one by focusing on a questionnaire designed especially for science laboratory classes. In particular, a description is given here of a convenient questionnaire which can be used by teachers to obtain a quick and easy assessment of their students' perceptions of their science laboratory classroom environment. A complete copy of this questionnaire, in a form that may be reproduced by teachers for use in their own classrooms, is provided as lift-out Supplements A and B. In addition, a description is given of scoring procedures and potentially useful applications of the new instrument.

SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI)

Supplements A and B contain two forms of the new questionnaire, called the *Science Laboratory Environment Inventory (SLEI)*, which is well-suited for use at the upper secondary and higher education levels. It is important to note that the SLEI is intended for use in situations in which a separate laboratory class exists.

The SLEI is economical in that it measures five different dimensions, yet it contains only 35 items altogether. Therefore, printing and collation costs are minimised. Also, because many teachers do not have ready access to computerised scoring methods, the SLEI has been designed to enable easy hand scoring.

The response alternatives for each item are *Almost Never, Seldom, Sometimes, Often* and *Very Often*. The scoring direction is reversed for approximately half of the items. Students' answers are recorded on the questionnaire itself to avoid errors that can arise in transferring responses to a separate answer sheet.

The items shown in Supplements A and B are arranged in cyclic order and in blocks of five to enable ready hand scoring. The first item in each block assesses Student Cohesiveness (SC); the second item in each block assesses Open-Endedness (OE); the third item assesses Integration (I); the fourth item assesses Rule Clarity (RC); and the last item in each block assesses Material Environment (ME). The meaning of these scales is clarified in Table 1 which contains a scale description and a sample item for each dimension.

Actual and Preferred Forms

In addition to a form which measures perceptions of *actual* environment, the SLEI has an additional form which measures *preferred* environment. The preferred form is concerned with goals and value orientations as it measures perceptions of the environment ideally liked or preferred. Although item wording is almost identical for actual and preferred forms, the directions for answering the two forms instruct students clearly as to whether they are rating what their class is actually like or what they would prefer it to be like. Supplement A contains the actual form and Supplement B contains the preferred form. It can be seen that an item such as "I work cooperatively in laboratory sessions" in the actual form is changed to "I *would* work cooperatively in laboratory sessions" in the preferred form.

Personal vs. Class Versions

Fraser and Tobin (1991) point out that there is potentially a major problem with nearly all existing classroom environment instruments when they are used to identify differences between subgroups within a classroom (e.g., boys and girls) or in the construction of case studies of individual students. The problem is that items in most scales are worded to obtain an individual student's perceptions of the class as a whole, as distinct from that student's

TABLE 1. Descriptive Information for Each Scale

Scale Name	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are supportive of one another.	I get along well with students in this laboratory class. (+)
Open-Endedness	Extent to which the laboratory activities emphasise an open-ended divergent approach to experimentation.	In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments. (-)
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	I use the theory from my regular science class sessions during laboratory activities. (+)
Rule Clarity	Extent to which behaviour in the laboratory is guided by formal rules.	There is a recognised way for me to do things safely in this laboratory. (+)
Material Environment	Extent to which the laboratory equipment and materials are adequate.	I find that the laboratory is crowded when I am doing experiments. (-)

\+ Items designated (+) are scored 1, 2, 3, 4 and 5, respectively, for the responses Almost Never, Seldom, Sometimes, Often and Very Often.

\- Items designated (-) are scored 5, 4, 3, 2 and 1, respectively, for the responses Almost Never, Seldom, Sometimes, Often and Very Often.

perceptions of his/her own role within the classroom. Although such classroom environment scales have been used to advantage in case study research (Tobin, Kahle & Fraser, 1990), these studies underline the desirability of having a new version of instruments available which are better suited to identifying differences.

For the reasons above, we developed a personal version of the SLEI which parallels its class version. Whereas Fraser, Giddings and McRobbie (1991) contains both the class and personal versions of the SLEI, it is the personal form which provides the focus for the present publication and which is provided in Supplements A and B.

Scoring

In order to score some of the items, the responses *Almost Never*, *Seldom*, *Sometimes*, *Often* and *Very Often* are given the scores of *1*, *2*, *3*, *4* and *5*, respectively. But, for the items with *R* in the *For Teacher's Use* column, reverse scoring is used so that *5* is given for *Almost Never* and *1* is given for *Very Often*, etc. Omitted or incorrectly answered items are given a score of *3*. The score for each of the *35* individual items can be written in the *For Teacher's Use* column.

The total score for a particular scale is simply obtained by adding the scores for the five items belonging to that scale. For example, the Student Cohesiveness scale total is obtained by adding the scores given to Items 1, 6, 11, 16, 21, 26 and 31, whereas the Material Environment total is the sum of the scores obtained for the last item in each block. The bottom of the questionnaire provides some spaces where the teacher can record the student's total score for each scale. Figure 1 shows how the questionnaire was scored to obtain a total of *23* for the Student Cohesiveness scale and *19* for the Material Environment scale.

Initial Development

The initial development of the SLEI was guided by the following criteria. A review of the literature was undertaken to identify dimensions that were considered important in the unique environment of the science laboratory class. Guidance in identifying dimensions also was obtained by examining all scales contained in existing classroom environment instruments for non-laboratory settings (Fraser, 1986). By interviewing numerous science teachers and students at the upper secondary and university levels and asking them to comment on draft versions of sets of items, an attempt was made to ensure that the SLEI's dimensions and individual items were considered salient by teachers and students. In order to achieve economy in terms of the time needed for answering and scoring, the SLEI was designed to have a relatively small number of reliable scales, each containing a fairly small number of items.

VALIDITY AND RELIABILITY

A set of items was written and passed through several successive revisions based on reactions solicited from colleagues with expertise in questionnaire construction and science teaching at the secondary and higher education levels. Careful attention was paid to making each item suitable for measuring both actual and preferred classroom environment. A series of item and factor analyses reported by Fraser, McRobbie and Giddings (1993) was used to improve the preliminary form and obtain the 35-item final form described in this publication.

Information about the reliability of SLEI scales is reported by Fraser, McRobbie and Giddings (1993) for the Australian sample, consisting of 1 875 senior high school students and 298 university students, described in Table 2. As well, reliability has been estimated for the larger six-country sample (Australia, USA, Canada, England, Israel, Nigeria) of 3 727 senior high school students and 1 720 university students also described in Table 2. Both the actual and preferred forms were administered to these samples.

When the actual form of the SLEI shown in Supplement A was administered to a new sample consisting of 516 senior high school chemistry students in 56 classes in Queensland, reliabilities (alpha coefficients) for class means were 0.80 for Student Cohesiveness, 0.80 for Open-Endedness, 0.91 for Integration, 0.76 for Rule Clarity and 0.74 for Material Environment. Similar values for the reliability occurred for the preferred form of the SLEI for the Australian sample, and for both the actual and preferred forms for the six-country samples described previously. These values indicate that the SLEI has satisfactory reliability for scales containing only seven items each.

	*Remember that you are describing your **actual** classroom.*	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1.	I get on well with students in this laboratory class.	1 2 3 4 (5)	5
2.	There is opportunity for me to pursue my own science interests in this laboratory class.	1 2 3 4 5	___
3.	What I do in our regular science class is unrelated to my laboratory work.	1 2 3 4 5	R ___
4.	My laboratory class has clear rules to guide my activities.	1 2 3 4 5	___
5.	I find that the laboratory is crowded when I am doing experiments.	1 2 3 4 (5)	R 1
6.	I have little chance to get to know other students in this laboratory class.	(1) 2 3 4 5	R 5
7.	In this laboratory class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	___
8.	The laboratory work is unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R ___
9.	My laboratory class is rather informal and few rules are imposed on me.	1 2 3 4 5	R ___
10.	The equipment and materials that I need for laboratory activities are readily available.	1 (2) 3 4 5	2
11.	Members of this laboratory class help me.	1 2 3 (4) 5	4
12.	In my laboratory sessions, other students collect different data than I do for the same problem.	1 2 3 4 5	___
13.	My regular science class work is integrated with laboratory activities.	1 2 3 4 5	___
14.	I am required to follow certain rules in the laboratory.	1 2 3 4 5	___
15.	I am ashamed of the appearance of this laboratory.	1 2 (3) 4 5	R 3
16.	I get to know students in this laboratory class well.	1 (2) 3 4 5	2
17.	I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1 2 3 4 5	___
18.	I use the theory from my regular science class sessions during laboratory activities.	1 2 3 4 5	___
19.	There is a recognised way for me to do things safely in this laboratory.	1 2 3 4 5	___
20.	The laboratory equipment which I use is in poor working order.	1 (2) 3 4 5	R 4
21.	I am able to depend on other students for help during laboratory classes.	1 2 (3) 4 5	3
22.	In my laboratory sessions, I do different experiments than some of the other students.	1 2 3 4 5	___
23.	The topics covered in regular science class work are quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R ___
24.	There are few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R ___
25.	I find that the laboratory is hot and stuffy.	1 2 3 (4) 5	R 2
26.	It takes me a long time to get to know everybody by his/her first name in this laboratory class.	1 2 3 (4) 5	R 2
27.	In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments.	1 2 3 4 5	R ___
28.	What I do in laboratory sessions helps me to understand the theory covered in regular science classes.	1 2 3 4 5	___
29.	The teacher outlines safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	___
30.	The laboratory is an attractive place for me to work in.	1 (2) 3 (4) 5	3
31.	I work cooperatively in laboratory sessions.	1 (2) 3 4 5	2
32.	I decide the best way to proceed during laboratory experiments.	1 2 3 4 5	___
33.	My laboratory work and regular science class work are unrelated.	1 2 3 4 5	R ___
34.	My laboratory class is run under clearer rules than my other classes.	1 2 3 4 5	___
35.	My laboratory has enough room for individual or group work.	1 2 3 (4) 5	4

For Teacher's Use Only: SC 23 OE ___ I ___ RC ___ ME 19

FIGURE 1. Illustration of Hand Scoring Procedures

TABLE 2. Description of Australian and Six-Country Samples of School and University Students

Schools/ Universities	Country	Sample Size	
		Students	Classes
Schools	Australia only	1 875	111
	All 6 countries combined	3 727	198
Universities	Australia only	298	24
	All 6 countries combined	1 720	71

USES OF SLEI

Fraser (1989a) has proposed a simple approach by which teachers can use information obtained from classroom environment questionnaires to guide attempts to improve their classrooms. The basic approach involves three aspects. First, assessments of student perceptions of both their actual and preferred classroom environment are used to identify differences between the actual classroom environment and that preferred by students. Second, strategies aimed at reducing these differences are implemented. Third, the classroom environment scales can be readministered to assess the success of the strategies in promoting changes. It is recommended that science teachers use this strategy in conjunction with the SLEI in attempts at improving laboratory class environments.

In particular, the proposed method for improving the climate of science laboratory classes can be especially useful as a basis for school-based staff development. Experience has shown that the administration and scoring of the SLEI can provide an excellent foundation for stimulating fruitful discussion and guiding improvement attempts as part of school-based professional development initiatives.

In past classroom environment research, it has been common to investigate associations between student outcomes and the nature of the classroom environment (Fraser, 1986). In order to permit investigation of the predictive validity (i.e., the ability to predict student outcomes) of the actual form of the SLEI, a large sample of Australian senior high school students responded to some scales which assessed attitudes towards science. Generally, the dimensions of the SLEI were found to be positively related with student attitude scores (Fraser, Giddings & McRobbie, 1993). In particular, students' attitude scores were higher in classrooms in which students perceived the presence of greater student cohesiveness, integration and rule clarity and a better material environment.

Previously, both researchers and teachers have found it useful to employ classroom climate dimensions as criteria of effectiveness in the evaluation of innovations, new curricula and new teaching methods (Fraser, 1986). Because of the high cost of laboratory teaching and the doubts expressed about its effectiveness, it is desirable that science teachers make use of the SLEI to monitor students' views of their laboratory classes, investigate the impact that different laboratory environments have on student outcomes, and provide a basis for guiding systematic attempts to improve these learning environments.

In previous research in several countries, students' and teachers' perceptions were compared. It has been found that, first, both students and teachers preferred a more positive classroom environment than they perceived as being actually present and, second, teachers tended to perceive the classroom environment more positively than did their students in the same classrooms. These findings have been replicated for the SLEI (Giddings & Fraser, 1990). These results are important because they suggest that teachers are likely to see their science laboratory classes 'through rose-coloured glasses' in the sense that teachers' perceptions typically are more positive than their students' perceptions.

CONCLUSION

This chapter describes a new questionnaire for assessing the climate of science laboratory classes either at the senior high school or the university level. A major purpose in producing this publication is to encourage science teachers to assess the environments of their own laboratory classrooms. Because classroom environment instruments can provide meaningful information about classrooms and a tangible basis to guide improvements, an economical, easily-administered, hand-scorable questionnaire is provided as part of this publication. Hopefully science teachers will make use of this classroom environment instrument in evaluating new curricula or teaching methods, checking whether the same classroom is seen differently by students of different genders, abilities or ethnic backgrounds, etc.

Noteworthy features of the SLEI include its consistency with the literature, its specific relevance to science laboratory classes and its salience to science teachers and students. Also, the SLEI has a personal version (involving a student's perception of his/her own role in the classroom), in contrast to most other existing instruments which have only a class version (involving a student's perceptions of the class as a whole).

A major l[illegible]tion of most past research which has investig[illegible]fferences in the environment scores of different subgroups of students within a class (e.g., students varying in gender, ethnicity or socioeconomic status) is that the traditional class version of instruments is not ideally suited to this research aim. Consequently, the existence of a personal version of the SLEI opens up the possibility of conducting more meaningful and sensitive investigations of the environments existing within a class for different subgroups of students.

REFERENCES

Fraser, B. J. (1986). *Classroom environment.* London, England: Croom Helm.

Fraser, B. J. (1989a). *Assessing and improving classroom environment* (What Research Says to the Science and Mathematics Teacher No. 2). Perth, Western Australia: Key Centre for School Science and Mathematics, Curtin University of Technology.

Fraser, B. J. (1989b). Twenty years of classroom climate work: Progress and prospect. *Journal of Curriculum Studies, 21,* 207-327.

Fraser, B. J., McRobbie, C. J., Giddings, G. J. (1993). Development and cross-national validation of a laboratory classroom environment instrument for senior high school science. *Science Education, 77,* 1-24.

Fraser, B., & Tobin, K. (1991). Combining qualitative and quantitative methods in the study of learning environments. In B. J. Fraser & H.J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 271-292). Oxford, England: Pergamon Press.

Fraser, B.J., & Walberg, H. J. (Eds.). (1991). *Educational environments: Evaluation, antecedents and consequences.* Oxford, England: Pergamon Press.

Giddings, G. J., & Fraser, B. J. (1990, April). *Cross-national development, validation and use of an instrument for assessing the environment of science laboratory classes.* Paper presented at the meeting of the American Educational Research Association, Boston, MA.

Hofstein, A., & Lunetta, V. (1982). The role of the laboratory in science teaching: Neglected areas of research. *Review of Educational Research, 52,* 201-207.

Pickering, M. (1980). Are laboratory courses a waste of time? *The Chronicle of Higher Education, 19,* 44-50.

Tobin, K., Kahle, J. B., & Fraser, B J. (Eds.). (1990). *Windows into science classes: Problems associated with higher-level cognitive learning.* London, England: Falmer Press.

SUPPLEMENT A

SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI)

Actual Form

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked **how often** each practice **actually takes place.**

There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

Think about how well each statement describes what this laboratory class is actually like for you. Draw a circle around

1	if the practice actually takes place	ALMOST NEVER
2	if the practice actually takes place	SELDOM
3	if the practice actually takes place	SOMETIMES
4	if the practice actually takes place	OFTEN
5	if the practice actually takes place	VERY OFTEN

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example. Suppose that you were given the statement: "I choose my partners for laboratory experiments." You would need to decide whether you thought that you **actually** choose your partners *Almost Never*, *Seldom*, *Sometimes*, *Often* or *Very Often*. For example, if you selected *Very Often*, you would circle the number 5 on your Answer Sheet.

Don't forget to write your name and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Assessing the Climate of Science Laboratory Classes* authored by Barry J. Fraser, Geoffrey J. Giddings and Campbell J. McRobbie and published by the national Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

NAME ______________________ SCHOOL ______________________ CLASS ______

Remember that you are describing your actual classroom.	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1. I get on well with students in this laboratory class.	1 2 3 4 5	___
2. There is opportunity for me to pursue my own science interests in this laboratory class.	1 2 3 4 5	___
3. What I do in our regular science class is unrelated to my laboratory work.	1 2 3 4 5	R ___
4. My laboratory class has clear rules to guide my activities.	1 2 3 4 5	___
5. I find that the laboratory is crowded when I am doing experiments.	1 2 3 4 5	R ___
6. I have little chance to get to know other students in this laboratory class.	1 2 3 4 5	R ___
7. In this laboratory class, I am required to design my own experiments to solve a given problem.	1 2 3 4 5	___
8. The laboratory work is unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R ___
9. My laboratory class is rather informal and few rules are imposed on me.	1 2 3 4 5	R ___
10. The equipment and materials that I need for laboratory activities are readily available.	1 2 3 4 5	___
11. Members of this laboratory class help me.	1 2 3 4 5	___
12. In my laboratory sessions, other students collect different data than I do for the same problem.	1 2 3 4 5	___
13. My regular science class work is integrated with laboratory activities.	1 2 3 4 5	___
14. I am required to follow certain rules in the laboratory.	1 2 3 4 5	___
15. I am ashamed of the appearance of this laboratory.	1 2 4 5	R ___
16. I get to know students in this laboratory class well.	1 2 3 4 5	___
17. I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1 2 3 4 5	___
18. I use the theory from my regular science class sessions during laboratory activities.	1 2 3 4 5	___
19. There is a recognised way for me to do things safely in this laboratory.	1 2 3 4 5	___
20. The laboratory equipment which I use is in poor working order.	1 2 3 4 5	R ___
21. I am able to depend on other students for help during laboratory classes.	1 2 3 4 5	___
22. In my laboratory sessions, I do different experiments than some of the other students.	1 2 3 4 5	___
23. The topics covered in regular science class work are quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R ___
24. There are few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R ___
25. I find that the laboratory is hot and stuffy.	1 2 3 4 5	R ___
26. It takes me a long time to get to know everybody by his/her first name in this laboratory class.	1 2 3 4 5	R ___
27. In my laboratory sessions, the teacher decides the best way for me to carry out the laboratory experiments.	1 2 3 4 5	R ___
28. What I do in laboratory sessions helps me to understand the theory covered in regular science classes.	1 2 3 4 5	___
29. The teacher outlines safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	___
30. The laboratory is an attractive place for me to work in.	1 2 3 4 5	___
31. I work cooperatively in laboratory sessions.	1 2 3 4 5	___
32. I decide the best way to proceed during laboratory experiments.	1 2 3 4 5	___
33. My laboratory work and regular science class work are unrelated.	1 2 3 4 5	R ___
34. My laboratory class is run under clearer rules than my other classes.	1 2 3 4 5	___
35. My laboratory has enough room for individual or group work.	1 2 3 4 5	___

For Teacher's Use Only: SC _____ OE _____ I _____ RC _____ ME _____

SUPPLEMENT B

SCIENCE LABORATORY ENVIRONMENT INVENTORY (SLEI)

Preferred Form

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked **how often** you would **prefer** each practice to take place.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

Think about how well each statement describes what your preferred laboratory class is like. Draw a circle around

1	if you would prefer the practice to take place	ALMOST NEVER
2	if you would prefer the practice to take place	SELDOM
3	if you would prefer the practice to take place	SOMETIMES
4	if you would prefer the practice to take place	OFTEN
5	if you would prefer the practice to take place	VERY OFTEN

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Practice Example. Suppose that you were given the statement: "I would choose my partners for laboratory experiments." You would need to decide whether you would **prefer** to choose your partners *Almost Never, Seldom, Sometimes, Often* or *Very Often*. For example, if you selected *Very Often*, you would circle the number 5 on your Answer Sheet.

Don't forget to write your name and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Assessing the Climate of Science Laboratory Classes* authored by Barry J. Fraser, Geoffrey J. Giddings and Campbell J. McRobbie and published by the national Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

NAME ______________________________ SCHOOL ________________________ CLASS _____

	*Remember that you are describing your **preferred** classroom.*	Almost Never / Seldom / Sometimes / Often / Very Often	For Teacher's Use
1.	I would get on well with students in this laboratory class.	1 2 3 4 5	____
2.	There would be opportunity for me to pursue my own science interests in this laboratory class.	1 2 3 4 5	____
3.	What I do in our regular science class would be unrelated to my laboratory work.	1 2 3 4 5	R ____
4.	My laboratory class would have clear rules to guide my activities.	1 2 3 4 5	____
5.	I would find that the laboratory is crowded when I am doing experiments.	1 2 3 4 5	R ____
6.	I would have little chance to get to know other students in this laboratory class.	1 2 3 4 5	R ____
7.	In this laboratory class, I would be required to design my own experiments to solve a given problem.	1 2 3 4 5	____
8.	The laboratory work would be unrelated to the topics that I am studying in my science class.	1 2 3 4 5	R ____
9.	My laboratory class would be rather informal and few rules would be imposed on me.	1 2 3 4 5	R ____
10.	The equipment and materials that I need for laboratory activities would be readily available.	1 2 3 4 5	____
11.	Members of this laboratory class would help me.	1 2 3 4 5	____
12.	In my laboratory sessions, other students would collect different data than I would for the same problem.	1 2 3 4 5	____
13.	My regular science class work would be integrated with laboratory activities.	1 2 3 4 5	____
14.	I would be required to follow certain rules in the laboratory.	1 2 3 4 5	____
15.	I would be ashamed of the appearance of this laboratory.	1 2 3 4 5	R ____
16.	I would get to know students in this laboratory class well.	1 2 3 4 5	____
17.	I would be allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	1 2 3 4 5	____
18.	I would use the theory from my regular science class sessions during laboratory activities.	1 2 3 4 5	____
19.	There would be a recognised way for me to do things safely in this laboratory.	1 2 3 4 5	____
20.	The laboratory equipment which I use would be in poor working order.	1 2 3 4 5	R ____
21.	I would be able to depend on other students for help during laboratory classes.	1 2 3 4 5	____
22.	In my laboratory sessions, I would do different experiments than some of the other students.	1 2 3 4 5	____
23.	The topics covered in regular science class work would be quite different from topics with which I deal in laboratory sessions.	1 2 3 4 5	R ____
24.	There would be few fixed rules for me to follow in laboratory sessions.	1 2 3 4 5	R ____
25.	I would find that the laboratory is hot and stuffy.	1 2 3 4 5	R ____
26.	It would take me a long time to get to know everybody by his/her first name in this laboratory class.	1 2 3 4 5	R ____
27.	In my laboratory sessions, the teacher would decide the best way for me to carry out the laboratory experiments.	1 2 3 4 5	R ____
28.	What I do in laboratory sessions would help me to understand the theory covered in regular science classes.	1 2 3 4 5	____
29.	The teacher would outline safety precautions to me before my laboratory sessions commence.	1 2 3 4 5	____
30.	The laboratory would be an attractive place for me to work in.	1 2 3 4 5	____
31.	I would work cooperatively in laboratory sessions.	1 2 3 4 5	____
32.	I would decide the best way to proceed during laboratory experiments.	1 2 3 4 5	____
33.	My laboratory work and regular science class work would be unrelated.	1 2 3 4 5	R ____
34.	My laboratory class would be run under clearer rules than my other classes.	1 2 3 4 5	____
35.	My laboratory would have enough room for individual or group work.	1 2 3 4 5	____

For Teacher's Use Only: SC _____ OE _____ I _____ RC _____ ME _____

Chapter 9

WRITING IN MATHEMATICS CLASSES

L. Diane Miller
Texas Tech University, United States of America

Students often do more writing in mathematics classes than in many other subjects, but typically the writing involves mathematical, not verbal, symbols. Mathematics is considered by many to be a language in its own right, with its own symbol system through which practitioners can think and express themselves. For this reason, the use of everyday spoken and written language in the learning and teaching of mathematics often is not appreciated.

The use of students' natural written language in the process of learning mathematics has been the focus of many research studies over the past decade. Mathematics educators in both the northern and southern hemispheres have been investigating ways of using writing in mathematics classes to enhance learning, diagnose misconceptions, and assess understanding and attitudes. Advocates of writing in mathematics believe that writing activities develop students' abilities to read, define and hypothesise; inculcate methods of problem solving; assist with the construction of knowledge; recognise attitudes; and promote individual teacher-student interaction.

The use of writing in mathematics classes can benefit both students and teachers. Some of these benefits are described in this chapter.

BENEFITS TO STUDENTS

Various types of writing have educational potential for mathematics teaching. These include: *journal writing*, which focuses on getting students to express their feelings about mathematics and the problems which they encounter in the learning process; *expository writing*, which has proven to be an effective and practical tool for teaching problem solving; and *transactional writing*, which can be used to motivate students towards developing an interest in mathematics and how it is used outside the classroom. Some benefits found for each of these types of writing are described below.

Journal Writing

Burton (1985) describes journal writing as "brainstorming with oneself". Everything is written down without evaluation. Thus, a journal becomes a student's 'think book' in which thinking about learning mathematics is done in writing. An example of one student's thinking is given by Borasi and Rose (1989):

> What is a linear programming problem? I still don't know! It has something to do with solving a system of equations to find the maximum or minimum value. It's used for things such as maximizing profits and minimizing costs. The object is to find the highest and lowest solutions. I forgot about the constraints! *(p. 355)*

Waywood (1991), an Australian researcher investigating the use of journal writing in the learning of mathematics, believes that journal writing can benefit students cognitively by leading them to summarise and reflect on the mathematics that they are learning. In a study involving approximately 500 students in Years 7-11, he saw evidence in journal entries of how different students organise their learning differently. For example, three students might record the same fact from a lesson, but one will merely state the fact, one will give an example of how the fact might be used, and the third might enter into a discussion of how the fact is related to other facts and how its status is questioned. The first student is simply recounting what happened in class; the second student is labelling the content in order to gain mastery; and the third has entered into a dialogue of interaction between a number of ideas.

The power of journal writing to influence attitudes is documented in the work of Nahrgang and Peterson (1986), Borasi and Rose (1989) and Clarke, Stephens and Waywood (1989). The work of these researchers illustrates how journal writing benefits students by providing them an opportunity to express their anxieties about and attitudes towards mathematics and the problems that they encounter in the learning process. The writing seems to have a therapeutic effect on the emotional components of learning mathematics, allowing students to vent their frustrations and reflect on their past and present feelings about school mathematics.

Expository Writing

Asking students to explain, in writing, their thinking about a nonroutine problem or mathematical investigation can be an effective and practical tool for teaching problem solving (Bell & Bell, 1985). More than reading and speaking, writing provides a context that encourages learning and thinking. In a study using two Year 9 mathematics classes in the United States, Bell and Bell (1985) demonstrated that writing positively affected students' progress in mathematical problem solving. One class was taught using a method which combined traditional teacher-centred, chalk-and-talk techniques with structured expository writing. For students who judged a specific problem to be easy, their writing described the process used in solving the problem and explained why it was easy.

For students who had difficulty in solving a problem or could not complete it, the writing became an opportunity to record the procedures used and the point at which confusion began. In other words, students put into words what was understood and what was not understood. The second class was taught using only the traditional teacher-centred, chalk-and-talk method. Both classes were given the same assignments, examples and assessments during the four-week period of the study. Only the writing component in the experimental class was different for the two teaching methods.

The results of the study support the use of expository writing in teaching problem solving. Pretests given to both groups before the study began showed no significant difference in the problem-solving skills of the two groups of students. However, four weeks after the study had been completed, the results of the posttest showed that the students doing the expository writing had better problem-solving skills than students following traditional methods.

Transactional Writing

Transactional writing is public writing meant to be read by an audience. In mathematics classes, the audience consists of other students or a teacher. It attempts to inform or persuade others towards a particular line of thinking. Essays about famous mathematicians and student-composed word problems are examples of transactional writings that can be used in mathematics classes. In general, Australian researchers, Reuille-Irons and Irons (1989), suggest that transactional writing activities "encourage children to be creators of their mathematical knowledge. When they create their own knowledge, they gradually build a picture of concepts and ideas that will be useful in problem-solving situations" (p. 98).

Ellerton (1986) investigated children's ability to make up problems and, through interviews, noted the need for more opportunities for children to share their often unspoken problems and beliefs about mathematics. Del Campo and Clements (1990) reinforced Ellerton's observations in their own research, which concluded that having students write creative stories helped them to construct more elegant mathematics, and reduced the passive nature of the mathematics classroom.

BENEFITS TO TEACHERS

Much of the research on writing in content areas has focused on student benefits. But what about benefits that teachers can derive from reading students' writings? Borasi and Rose (1989) suggest that teachers, too, could be equally affected in their teaching by reading their students' writings. Birken (1989) admits to learning a great deal about her students' mathematical thinking, particularly their misconceptions and where their thinking went wrong. My own research (Miller 1991) documents how reading students' writings in first-year algebra classes revealed how students comprehended or misconstrued specific concepts and algorithms.

In general, however, there is a dearth of literature addressing the effect which the use of writing in mathematics has on teachers. Thus, the purpose of a study conducted in Perth, Western Australia, was to examine the benefits which secondary teachers derived from reading their students' writings in mathematics. The remainder of this publication focuses on the study and its findings.

DESCRIPTION OF THE STUDY

The study was undertaken by a research team consisting of three secondary mathematics teachers, each having 15 or more years of teaching experience, and two mathematics educators from the national Key Centre for Teaching and Research in School Science and Mathematics at Curtin University. The teachers were from three different schools, one private and two government. Each teacher agreed to implement writing activities in one of his/her classes. One chose Year 11 *Introductory Calculus* students, one elected to implement writing in a *Mathematics for Living* class for Year 9 students, and one asked a class of Year 10 students to write in their mathematics class. The Year 10 and 11 students were considered to be above average academically by their teachers and the Year 9 *Mathematics for Living* students were described as below average.

In-class, impromptu writing prompts – simply-worded statements or questions directing students' thoughts to the explanation of a single concept, skill or generalisation – were utilised in this study. For example, one prompt asked Year 9 students to explain to a primary-aged student how the year is divided into units of time. (For a more detailed description of writing prompts, see Miller, 1990.) The writing period was timed. Two teachers chose to allow five minutes for the activity; one teacher allowed students to write for 10 minutes. All three teachers asked students to write at the beginning of the class and agreed to use writing prompts approximately three out of every five teaching days. The prompts were either written on the chalkboard or given to each student on a sheet of paper. The teachers collected writings during the second and third terms of the 1991 school year. In addition to reading the students' writings, the teachers agreed to produce a written response to their dominant impressions of the students' writings. The whole research team met four times during the course of the study to discuss the students' writings and, specifically, the benefits being derived by the teachers as a result of reading their students' writings.

WHAT TEACHERS LEARNED FROM THE STUDENTS' WRITINGS

Limitations in Students' Understanding

All three teachers believed that their assessment of individual students' understanding of mathematical concepts, skills and generalisations was enhanced by reading the students' responses to the in-class, impromptu writing prompts. One instance described by the teacher of the Year 9 students related to how she used a prompt to diagnose students' prior knowledge about averages. She asked them to respond to the question "What is an average?" Of the 11 students in the class, four briefly outlined how the numbers were added and then divided by the number of numbers added. That is, they described how to find a mean, but did not use the word 'mean'. Four students used phrases like 'a number in between other numbers', and one student said that an average was the number used most often, interpreted by the teacher as meaning the mode, but the student did not use the word 'mode' in his/her writing. Two students wrote meaningless, unacceptable responses.

One week later, after much teacher and student activity involving the three different types of averages (mean, median and mode) the teacher repeated the prompt "What is an average?" to assess the students' understanding after instruction. Twelve students were present that day but, to her disappointment, only one student from the original 11 significantly revised his response. Six students referred to average as being the number in the middle'. Four of these six students used the word 'mean' in reference to 'the number in the middle'. One student described how to find a mean using the word 'mean' in her writing. Two students accurately described and used the word 'mode' and one student described mode but did not use the word 'mode'. One student described all three types of averages using the words 'median', 'mode' and 'average' for mean. One student chose not to respond. The teacher's writing after reading this collection of papers is given below:

> We had discussed the fact that there are other types of 'averages' not just the mean. However only one student has mentioned this. Back to the drawing board again! Do they have preconceived ideas which they hang on to? *(Teacher's log, 21 May 1991)*

Teachers' assumptions about students' prior knowledge often surfaced in comments and writings by the teachers. During a team meeting, another teacher said:

> I found by reading the students' writings that, in some instances, the points I have emphasised in teaching a concept did not always coincide with what the students needed to hear to actually gain an understanding of the concept. After reading what they wrote, I knew what I should have emphasised to more fully explain the concept.

> I had made wrong assumptions about their knowledge and background. That sort of thing has happened to me in different situations. *(Transcribed tape, 3 October 1991)*

All three teachers described instances, both verbally during team meetings and in their individual writings, when they had retaught a topic because the students' writings did not reflect a comprehension of the topic covered in a previous lesson. All three talked about how they had assumed that the students understood what was 'going on', but that their writings often indicated that they did not. Comments referring to students' understanding as reflected by their ability to manipulate symbols and numbers were frequent. However, when an acknowledgment of their understanding was requested using written language, the students often failed to submit acceptable responses.

Limitations in Students' Understanding and Ability to Use Mathematics Vocabulary

Mathematics teaching and learning is an interactive process which depends on the understanding of carefully defined terms and symbols. Understanding, in turn, is dependent upon a student's knowledge of mathematics vocabulary. Teachers use mathematics vocabulary routinely in the teaching-learning process, assuming that students have previously acquired meaningful definitions for words which might have been introduced several years previously. Without a command of the language used in mathematics teaching, the task of comprehending a teacher's comments, reading a mathematics textbook or solving a word problem becomes extremely difficult for students.

After only two writing prompts, one of the teachers in the study wrote: "At this stage, I'm already concerned that a number of students do not have a good understanding of key mathematical words." (Teacher's log, 3 May 1991). He continued to voice his concern at the next team meeting by saying:

> I've been worried about their lack of understanding of key words. I find, when I look at the explanations, that they're not very good explanations. For example, in their writings they all say 'the number in front of x' or whatever the variable is. They do not use the word 'coefficient' and I know that they know what it means. *(Transcribed tape, 27 May 1991)*

Throughout the study, the teachers reiterated their dismay at students' lack of use and inappropriate use of mathematics vocabulary. The following three responses are representative of the 16 students in one Year 11, *Introductory Calculus* class. The prompt asked students to "Explain what occurs when h is a divisor and $h \rightarrow 0$":

Student A: When h is a divisor and h → 0, ~~the quotient being divided~~ the answer arrived at would become increasingly larger as h decreases. At zero, h is ~~infinite~~ undefined as nothing can be divided by zero.

Student B: As h approaches zero the dividend of the equation becomes very large.

Student C: If the number that the divisor is going to be divided into is small, and the closer h gets towards zero, then the larger the answer is 'going to be'.

Student A uses the word 'quotient' but marks it out to signal some doubt as to the use of the word. He is more comfortable saying 'the answer arrived at'. Student B has confused 'dividend' with 'quotient', while Student C describes but does not use the word 'dividend'. Rather than saying 'quotient', Student C also chose to say 'the answer'. In this study, the lack of use and the inappropriate use of mathematics vocabulary by students ranging in academic ability from below average to above average was disturbing to the three teacher researchers.

Two of the three teachers indicated that they changed their teaching practices to accommodate what they were learning about students' knowledge and use of mathematics vocabulary. All three confirmed that one value of writing in mathematics classes was giving students an opportunity to use mathematics vocabulary and for teachers to assess their use and understanding of specialised terms. In an interview at the end of the study, one of the teachers said:

> You know, teachers have got to change their language to become better role models for the students. We have got to use the correct vocabulary. I tried to emphasise key words throughout the course after the first five or six prompts. After I started using the right words, I think that the students started becoming more comfortable and the words automatically came to their mind a lot more quickly with the writing. *(Transcribed tape, 3 October 1991)*

STUDENTS' WRITINGS INFLUENCE TEACHERS' PRACTICES

In addition to enhancing teachers' assessment of students' understanding and informing teachers of students' knowledge and use of mathematics vocabulary, the writing activities influenced the teachers' practices. Various comments made at team meetings and in teachers' logs confirmed that reading students' writings helped teachers to know when they had successfully achieved a lesson's objectives. The writings sometimes suggested when a lesson should be retaught and what should be restated, perhaps in a different way, in order to assist students in constructing their knowledge about a specific concept or topic.

The comments and writings of the teachers in this study lend support to the results of a previous study which suggested that writing in mathematics classes can influence teaching practices in at least five ways (Miller, in press). After reading their students' writings, teachers can decide to (a) immediately reteach a lesson or concept, (b) delay an assessment because a lack of understanding is reflected in the students' writings, (c) schedule a revision based upon what was learned from the students' writings, (d) initiate private discussions with individual students who have mathematical misconceptions, and (e) use writing prompts on assessments where students are given a mark for their ability to communicate their knowledge and understanding of mathematics in writing.

Preparing the prompts and reading the students' responses do take time. At the end of the study, all three teachers were asked if they would continue to use impromptu writing prompts during the fourth term, even though the study was officially over. Everyone said yes, although they felt that they might not ask the students to write as often. One teacher's comment represents the sentiments of all three:

> Yes, I was telling [teacher's name] that I would continue, especially with the group that is doing it now. I will be teaching newer areas and I'm sure that I'll try to think of something to get them to write. It probably won't be as frequent, because it does take a fair bit of time to read through and do these sorts of things. But, when there is a degree of uncertainty coming through in my mind as to whether they are understanding something, or if we have something new, then I'll be looking at it [writing] as a way to find out what they are thinking. *(Transcribed tape, 3 October 1991)*

GETTING STARTED

The following five suggestions could prove helpful to teachers who decide to implement writing activities in their mathematics classes:

Suggestions for Getting Started

1. Decide on a definite period of time for in-class writing and when you want the students to write. Teachers who have used impromptu writing prompts recommend having students write at the beginning of class for a five-minute interval.
2. When preparing a lesson, write prompts that relate to that lesson; however, be flexible, because sometimes ideas for prompts surface during a class. If this happens, use that idea the next day rather than a preplanned prompt.
3. As past research suggests that students write more if they address their comments to someone (Miller & England, 1989), student responses could be addressed to their best friend.
4. Do not always offer students extrinsic incentives such as points towards a final grade. Talk with students about the purpose of the experience and solicit their cooperation on the merits of it being a meaningful and beneficial experience for you and them. Likewise, do not penalise students when they do not write. In past studies, even the most difficult student, with time, has started writing.
5. Be patient. The benefits of writing activities in mathematics classes do not surface immediately. Students first must get accustomed to the idea of writing in mathematics class. Initial writings can be very brief and meaningless to the teacher. Give students time to learn how to write in mathematics and the rewards should follow.

CONCLUSION

This chapter describes how writing in mathematics classes can be beneficial to students and their teachers. More specifically, it has reported the results of an Australian study which examined benefits derived by teachers from reading their students' responses to timed, in-class, impromptu writing prompts.

Writing in mathematics classes is not a panacea for every teacher. It works and is very rewarding for some teachers, but not necessarily for others. Questions raised by some critics include: "What's so unique about writing in mathematics classes?" "Can't teachers learn the same things by asking students questions in class?" While teachers can ask open-ended, thought-provoking questions in class or pose them in a context of small-group activities, only a few students become involved in these discussions. Allowing sufficient time for students to formulate and respond to open-ended questions orally can create a lull during which other students can become off-task mentally; if not physically, too. Within the time allotted for teacher-student interaction in class, a teacher usually cannot interact with every student in a class of 20-30 students. A unique feature about impromptu writing prompts is that each student has the opportunity to express her/himself, in writing, to the teacher during every class in which a prompt is used. Writing also allows students an opportunity to examine their thoughts and make changes in their statements prior to submitting their response. Generally students answering orally do not have the chance to say something, reflect upon what they have said and then make changes to those statements. The teachers in this study found that five minutes was sufficient time for students to read and respond to a prompt, but it did not disrupt their other teaching practices.

Another benefit of writing in mathematics classes is that it gives students an opportunity to communicate their understanding of mathematics and to use mathematics vocabulary in writing. *A National Statement on Mathematics for Australian Schools* (1990) suggests that all students should learn to communicate mathematically and that a command of mathematical terminology is essential in learning mathematics. The purpose of this chapter has been to stimulate teachers to think about the use of writing in mathematics, first, as a means to assess students' understanding of mathematics and use of mathematics vocabulary and, second, as a way to diagnose students' needs in the process of learning.

REFERENCES

Australian Education Council. (1990). *A national statement on mathematics for Australian schools.* Carlton, Victoria: Curriculum Corporation.

Bell, E. S., & Bell, R. N. (1985). Writing and mathematical problem solving: Arguments in favor of synthesis. *School Science and Mathematics, 85*(3), 210-221.

Birken, M. (1989). Using writing to assist learning in college mathematics classes. In P. Connolly & T. Vilardi (Eds.), *Writing to learn mathematics and science* (pp. 33-47). New York, NY: Teachers College Press.

Borasi, R., & Rose, B. J. (1989). Journal writing and mathematics instruction. *Educational Studies in Mathematics, 20*, 347-365.

Burton, G. M. (1985). Writing as a way of knowing in a mathematics education class. *Arithmetic Teacher, 33*(4), 40-45.

Clarke, D., Stephens, M., & Waywood, A. (1989). Improving students' learning in mathematics through diaries, journals and other communications. In B. Doig (Ed.), *Every one counts* (pp. 454-460). Melbourne, Victoria: Mathematical Association of Victoria.

Del Campo, C., & Clements, M. A. (1990). Expanding the modes of communication in mathematics classrooms. *Journal für Mathematik-Didaktik, 11*(1), 45-79.

Ellerton, N. F. (1986). Children's made-up problems – A new perspective on talented mathematicians. *Educational Studies in Mathematics, 17*, 261-271.

Miller, L. D. (1990). When students write in algebra class. *The Australian Mathematics Teacher, 46*(2), 4-7.

Miller, L. D. (1991). Constructing pedagogical content knowledge from students' writing in secondary mathematics. *Mathematics Education Research Journal, 3*(1), 30-44.

Miller, L. D. (in press). Teacher benefits from using impromptu writing prompts in algebra classes. *Journal for Research in Mathematics Education.*

Miller, L. D., & England, D. A. (1989). Writing to learn algebra. *School Science and Mathematics, 89*(4), 299-312.

Nahrgang, C., & Peterson, B. T. (1986). Using writing to learn mathematics. *Mathematics Teacher, 79*(6), 461-465.

Reuille-Irons, R., & Irons, C.J. (1989). Language experiences: A base for problem solving. In P. R. Trafton & A. P. Schulte (Eds.), *New directions in elementary school mathematics* (pp. 85-98). Reston, VA: National Council of Teachers of Mathematics.

Waywood, A. (1991, July). *Journal writing and learning mathematics.* Paper presented at the meeting of the Mathematics Education Research Group of Australasia, Perth, Western Australia.

Chapter 10

TECHNOLOGY EDUCATION IN SCIENCE AND MATHEMATICS

Jan Harding
Alresford, Hampshire, United Kingdom

Léonie J. Rennie
Curtin University of Technology

There are many ways to think about technology. People think about it in ways that fit their circumstances and experiences. In response to a request to define technology, one science teacher wrote:

> Technology is the 'applied knowledge' of science. Technology minus 'science' does not exist. Therefore technology may be defined as the practical off-shoot of science.

The theme 'technology as applied science' was a popular one among 94 Australian science teachers who were asked to respond to this question (Rennie, 1987). That's not surprising – they were, first and foremost, science teachers! Here's what another teacher wrote in answer to the same question:

> Technology is the development of instruments useful in simplifying mathematical calculations and processes after appropriate algorithms have been fed into the instrument.

You might not be surprised to learn that this definition came from a mathematics teacher or that, when mathematics teachers wrote about equipment in technology, they usually mentioned computers and calculators.

But these aren't the only kinds of things which teachers write about technology. Artefacts, procedures to make work easier and interaction with society are also mentioned. Below are two more examples, the first from a mathematics teacher, and the second from a science teacher:

> Technology includes the artefacts/implements/instruments/procedures developed/invented by a community/society in order to advance itself culturally/professionally and to improve its living standards.

> A culture-bound phenomenon which makes tasks easier. Technology incorporates a range of tools from the very simple to the very complex.

Students have different ideas about technology, too. They mostly agree that it is important, but many don't realise how diverse and pervasive it is. Some think of technology in terms of computers, some in terms of environmental disaster. Others think about inventing, manufacturing and progress with positive and negative consequences (Rennie & Sillitto, 1988).

Technology has become part of the curriculum in Australia and what science and mathematics teachers and their students think about technology has become very important. Teachers of subjects like technical drawing, home economics and manual arts often have been assumed to be the technology specialists. Now it seems that teachers in other subjects, like mathematics and science, have an increasingly important role to play. What does this mean for science and mathematics teachers? What will they have to know? What will they have to do? Developments all over the world indicate that teachers need to understand technology as a whole curriculum theme, not just as it relates to mathematics or science. At the same time, the special relationship between technology and their own subject needs to be examined. Further, teachers need to consider children's ideas and how they think about technology, because whatever happens in the classroom will be shaped not only by what teachers do but by what students think.

In this issue of *What Research Says ...*, we explore the concept of technology and the nature of technology education. We look at recent curriculum developments in technology and what they mean for teachers of mathematics and science. So that they can develop lessons which take account of students' views, we describe three methods which teachers could use to find out what their students think about technology.

WHAT IS TECHNOLOGY?

Gardner, Penna and Brass (1990) analysed a number of descriptions of technology from the literature associated with curriculum development. They identified six recurring elements: technology is concerned with *people* (a human endeavour); *purposes* (satisfaction of human needs or wants); *resources* (materials, energy, capital, time); *tools and machines* (to extend capabilities); *processes* (storing, transforming, transporting); and *products* (artefacts). They also emphasised the technological process, listing *invention* (of a new idea), *refinement* (of the invention), *innovation* (making it available to the public), *diffusion* (the uptake of the innovation) and *transfer* (to a new society or country).

It is clear that technology involves both products and processes, including designing, producing, refining and marketing. All of this occurs in a social context. If we understand technology in this broad way, how does it help us to understand what technology education might be, especially as it affects science and mathematics teachers?

WHAT IS TECHNOLOGY EDUCATION?

Technology education is much older in the UK than in Australia, and developments here have been informed by the UK experience. The Association for Science Education (ASE) set up a working party to explore science curricula and technology in the UK. It commented on the inadequacies of ad hoc developments, such as approaches dominated by craft teachers, 'hi-tech' courses focusing on computers and electronics, pre-engineering courses, or science courses with an applied science component. The ASE report (Woolnough, 1988) identified four components to technology education:

- technological literacy, in which students become familiar with the content and methodologies of a range of different technologies;
- technological awareness, in which students are made aware of personal, moral, social, environmental and economic implications of technology;
- technological capability, in which students tackle a variety of technological problems considering a range of perspectives;
- information technology, in which students obtain, handle and communicate information.

These four components have implications for how technology might be incorporated into the curriculum. In the UK, *Technology* was first introduced in 1990 as one of the 10 curriculum subjects of the National Curriculum for pupils aged 5-16 years. The curriculum structure has emphasised technological capability and information technology, although technological awareness and literacy also play a role. However, according to an HMI report, teachers have found problems in interpreting and implementing the requirements of the curriculum and it is now under revision.

What kinds of curriculum decisions are being made in Australia? The Australian Education Council has proposed that all States include technology as a separate curriculum strand. There is a national curriculum statement about technology education which has not been released yet. Independently, several Australian States have included *Technology* in recent curriculum statements. In Western Australia, *Science and Technology* (which includes computer studies) has formed one of seven components of the K-10 curriculum from 1985. One school has integrated its technology program across the curriculum, and tied it in with the four ASE components (Treagust & Mather, 1990). Another curriculum project has emphasised technological capability, resulting in a textbook for teachers of Years 5 to 8 (Treagust, Kinnear & Rennie, 1991). Students work on design projects related to leisure, toys and the zoo.

Technology is included in the New South Wales Statement of Curriculum as part of the *Technological and Applied Studies* Key Learning Area in secondary schools. In primary schools, technology is linked with science. The *Technology Studies* subject introduced in 1990 in schools in New South Wales has two strands, one focusing on computer software applications and the other on technology studies. In the latter strand, students are expected to learn about technology, to use technologies and to design, research and assemble a project. Such a program reflects the four components of technology outlined by the ASE.

In Victoria, *Technology Studies* is one of the P-10 Curriculum Frameworks and has the subtitle *Thinking, Making, Doing* (Ministry of Education, Victoria, 1988). The curriculum also emphasises technological capability with its strong bias to the technological process (inventing, planning, evaluating) and student outcomes are defined in terms of knowledge and skills relating to technology, the understanding and use of the technological process, technology and society, and personal development.

WHAT IS THE ROLE OF SCIENCE AND MATHEMATICS TEACHERS?

In May 1990, the second meeting of the Prime Minister's Science Council was devoted to 'Science and Mathematics in the Formative Years' and included discussion of curricula, teachers and learners. In his comments on this topic, Fensham states:

> I suspect the various concerns about mathematics and science education in Australia ... could be well summarised as a wish for a *'practical capability'* in our students in mathematics and science that will enable them *to think, live, and to act in the technological world we have chosen for them. (Fensham, 1990a, p. 138)*

The implication is that high-quality learning in mathematics and science will produce citizens who are confident and capable, people who can think and act in a socially responsible way. Fensham (1990b) examines the ability of our present science courses to prepare students in the three areas of technological awareness, literacy and capability. Changes in science education have moved towards making students aware of technology, but only by presenting it as applications of science. In contrast, some science courses, notably the Salter courses in the UK, start from technological issues or from where technology impinges on the lives of young people. Such courses are more likely to develop technological awareness and literacy together with a sense of confidence and social responsibility. Fensham questions whether Australia's science courses in their present form can develop technological capability. His paper makes interesting reading for teachers willing to think critically about the science content of our curricula.

Even if new science and mathematics courses are developed which will encourage technological capability in our students, whether they develop technological literacy, the confidence to deal with technology in a socially responsible way, remains to be seen. Experience elsewhere suggests that we should look carefully at the outcomes.

An example comes from a large London comprehensive secondary school. Here, the students who had followed a three-year technology course (during Years 7-9) were asked to complete one of the following sentences:

> It is important for me to know about science and technology because ...
>
> It is not important for me to know about science and technology because ...

Most students completed the first sentence. Their reasons fell into three categories: competency – do-it-yourself construction and repair jobs (girls and boys equally made this response); careers – to help you get a job (boys more than girls gave this response); and interpretive – to help you to live with confidence in the world (responses of this kind were almost three times as likely to come from girls as from boys) (Grant & Harding, 1987). There is no doubt that students learned from the course, but their learning outcomes were presented differently. The boys were focusing more on technological capability (the doing of technology) and the girls on technological literacy.

The importance of values and social responsibility cannot be overlooked. Our science and mathematics courses are heavily weighted towards knowledge, in spite of recent curriculum projects which have emphasised process or skills. Technology courses have emphasised skills, with a shift from craft skills to those of problem solving. Neither has included a strong values component. Importantly, several studies have shown that girls are more likely to be motivated to study science and technology when a consideration of values is integrated within the course (Grant & Harding, 1987). A technology course which emphasises values could encourage not only more equitable participation, but also provide a vehicle for technological critique and the consideration of social responsibility.

The need for a social and critical aspect in technology education in Australia is clear. Eckersley (1987) reported to the Commission for the Future on the attitudes of Australian people to science and technology. He concluded that "Australians applaud technological progress, and fear it" (p. 1). Nuclear weapons, pollution and computers "appear to be a major source of pessimism many Australians feel about the future"

(p. 3). He notes that many teenagers could not imagine a peaceful and desirable future.

Teachers, including mathematics and science teachers, share a responsibility to help students cope with our technological world. It also makes it very important to understand what our students think about technology and its relationship to them.

WHAT DO YOUR STUDENTS THINK ABOUT TECHNOLOGY?

What students learn in your classroom depends not only on what you plan for them to learn, but on the knowledge and understandings which they bring to the topic. What goes on in their heads is shaped by what is already there. If you can find out your students' current thinking and understanding of technology, you will know where to start. You'll be in a position to help students challenge their ideas, if that is appropriate, and offer opportunities for them to develop their understanding.

Here are descriptions of three ways of obtaining information about students' perceptions of technology: writing an essay; responding to a survey; and drawing a picture. The different methods give different information and each has some advantages and limitations.

Writing about Technology

Give each student a piece of paper containing the following essay topic, and ask them to write at least three sentences:

> Technology can mean different things to different people. When you read the word 'technology' what comes into your mind? What does technology involve?

Ten minutes seems to be an adequate amount of time to give students to write about this topic. If you want longer essays, you can give more time.

You'll find that the essays from your class will make interesting reading. There might be a local issue upon which your students could comment, but probably you will find a wide range of responses. Some will make good discussion topics, or perhaps you could get groups of students in the class to use their essays and come to a consensus definition for technology.

Rennie and Sillitto (1988) collected 212 essays on the above topic from 13-year-old students in Western Australia. They found a large variation in how much students wrote, and what they wrote about. Overall, students wrote about technology in terms of: its products, like computers and machines; its processes, like invention and manufacturing; and its social aspects, like good and bad consequences.

The content of these Western Australian essays was very similar to that written in other countries. The technology essay topic was prepared by a team of researchers led by Jan Raat and Marc de Vries from Eindhoven, The Netherlands. Their project, called *Pupils' Attitudes Towards Technology (PATT)*, coordinated the collection of data relating to students' attitudes and knowledge about technology in many countries in the world.

Responding to a Questionnaire

The PATT project also developed very comprehensive attitude questionnaires about technology, including questionnaires about interest, gender-role pattern, consequences, difficulty and careers in technology. Some of these have been adapted for use in schools in Western Australia (Rennie & Treagust, 1989).

The Supplement to this document has two short questionnaires about technology. *Part A – What is Technology?* asks students questions about the nature of technology. The five odd-numbered statements investigate the breadth of students' understanding of technology. 'Agree' responses indicate a narrow perspective. The five even-numbered statements assess students' understanding of technology as a design process – the thinking-making-doing concept of technology. 'Agree' responses indicate agreement with this perspective.

Part B – What Do You Think About Technology? concerns students' attitudes about technology. For the five odd-numbered statements, 'Agree' responses indicate that students have a positive interest in technology. The even-numbered statements refer to the social implications of technology. 'Agree' responses indicate that students' perceive technology to have favourable consequences. 'Disagree' responses indicate that students perceive technology in a negative way.

Photocopy the page in the Supplement if you would like your students to respond to these items. All of the items have been used before, and the four kinds of items form four subscales to do with the diversity of technology (Part A, odd-numbered items), technology as a design process (Part A, even-numbered items), students' interest (Part B, odd-numbered items) and perceptions about the social implications of technology (Part B, even-numbered items).

If you use the questionnaire to find out about students' perceptions of technology, there's no need to work out scores on subscales. It's probably more informative just to get a picture of the pattern of responses for each of the items. This will give you a starting point for future discussions or lessons about technology. If you did want to use subscales to make comparisons between classes, for example, just add up the scores on each item of the subscale.

Many students, particularly girls, respond in the middle category on items like these, particularly those about the social aspects of technology. Grant and Harding (1987) investigated further why so many students chose in this category, and concluded that they often suspend judgement – the decision to agree or disagree depends on the circumstances. The items just didn't have enough information for these students to decide which aspects of technology were referred to. Class discussion of some of the issues has led to lively debate.

Drawing a Picture about Technology

A third way to find out what students think about technology is to ask them to draw a picture about 'what technology means to me'. This is good fun for upper primary and lower secondary classes, and many students will draw clever and interesting cartoon figures and situations. Often they need to be interpreted 'tongue-in-cheek'.

This is a similar technique to the Draw-a-Scientist task which appeared in *What Research Says... No. 4* (Kahle, 1990). But be careful about how you phrase the instructions for the drawing! 'Draw a technologist' or 'draw a person involved in technology' will probably give you quite a different picture. Be clear what you want to find out, then give the instructions. A sample set of instructions is contained in the supplement, combined with the essay question. Some students might complain that they can't draw, but this doesn't matter – stick figures, outlines and labels will help to overcome any lack of artistic skills.

Sit down and think about the drawings you get. You might want to sort them into groups which represent particular perceptions of technology. For example, some might focus on machinery, others might involve advances in medicine. Space travel is a popular theme. People who have used drawings as a way of getting at students' ideas have found that some drawings can express strong emotions representing fear of technological appliances, like computers, and concern for the future of our planet and ourselves.

Which Method Works Best?

Choosing the best method of finding out what students think about technology depends on what you want to know. Essays give students the opportunity to write about what *they* think is important but, if a particular aspect of technology isn't mentioned, you can't assume that they don't know about it. Drawings also give students free reign, and can elicit strongly positive or negative attitudes which students might not want to write in an essay. Essays are more likely to stick to ideas and 'facts'. The age of the student is also important in deciding whether to use an essay, a drawing or both.

If you want all students to give their ideas about the *same* aspects of technology, a questionnaire might be useful. Instead of using the items given here, you could make up your own. It is a bit more time-consuming (and not as much fun) to count responses on questionnaires than to read essays or look at drawings, but the information can be very helpful. And there are ways to make the counting easier – for example, shuffle then redistribute the unnamed questionnaires to students and use a show of hands to get the number choosing each response category for each question.

CONCLUSION

We began by discussing technology and technology education. Current thinking about technology education suggests that there are four aspects to be considered: technological literacy, technological awareness, technological capability and information technology. Assisting students to achieve technological capability appears to be an important challenge for science and mathematics teachers. It is also clear that technological literacy must be included in a technology course if students are to develop a sense of social responsibility and confidence as users of technology.

How technology education will affect science and mathematics curricula in Australia still is being decided. However, teachers' own views of technology and the views of their students will play a crucial role in determining the outcomes of those courses. We have described three methods which teachers could use to find out their students' ideas about technology so that those ideas can be built into whatever course is offered. Whatever turns out to be the formal role of mathematics and science teachers in technology education, it is sure to be one of considerable influence on the future of our students.

REFERENCES

Eckersley, R. (1987). *Australian attitudes to science and technology and the future* (A report for the Commission of the Future). Carlton, Victoria: Australian Government Printing Service.

Fensham, P. J. (1990a). Response to curricular, learners and teachers. In S. Willis (Ed.), *Science and mathematics in the formative years* (pp. 135-146) (Papers for the Prime Minister's Science Council). Canberra, Australian Capital Territory: Australian Government Printing Service.

Fensham, P. J. (1990b). What will science do about technology? *The Australian Science Teachers' Journal, 36*(3), 8-21.

Gardner, P. L., Penna, C., & Brass, K. (1990). Technology and science: Meanings and educational implications. *The Australian Science Teachers' Journal, 36*(3), 22-28.

Grant, M., & Harding, J. (1987). Changing the polarity. *International Journal of Science Education, 9*, 335-342.

Kahle, J. (1990). *Images of scientists: Gender issues in science classrooms* (What Research Says to the Science and Mathematics Teacher No. 4). Perth, Western Australia: Key Centre for School Science and Mathematics, Curtin University of Technology.

Ministry of Education (Schools Division) Victoria. (1988). *The technology studies framework P-10*. Melbourne, Victoria: Ministry of Education (Schools Division).

Rennie, L. J. (1987). Teachers' and pupils' perceptions of technology and the implications for curriculum. *Research in Science and Technology Education, 5*, 121-134.

Rennie, L. J., & Sillitto, F. J. (1988). The meaning of technology: Perceptions from the essays of Year 8 students. *The Australian Science Teachers' Journal, 34*(4), 68-76.

Rennie, L. J., & Treagust, D. F. (1989). Measuring students' attitudes and perceptions about technology: A multidimensional concept. *Research in Science Education, 19*, 221-230.

Treagust, D. F., Kinnear, A., & Rennie, L. J. (1991). *Teaching technology as a design process*. Perth, Western Australia: Science Teachers' Association of Western Australia.

Treagust, D. F., & Mather, S. H. (1990). One school's approach to technology education: Integration across the curriculum. *The Australian Science Teachers' Journal, 36*(3), 50-60.

Woolnough, B. E. (Chairman) (1988). *Technological education and science in schools* (Report of the Science and Technology Sub-committee for the Association of Science Education). Hatfield, Herts: Association for Science Education.

SUPPLEMENT

TECHNOLOGY QUESTIONNAIRE

Name ______________________ School ______________________ Class ________

Here are some questions for you. For each question, circle the number which is the right answer for you.

Part A: What is technology?

	STRONGLY AGREE	AGREE	CANT DECIDE	DISAGREE	STRONGLY DISAGREE
1. Technology mainly concerns computers and similar equipment.	1	2	3	4	5
2. Making models and testing them is part of technology.	1	2	3	4	5
3. Technological appliances can only be used by qualified people.	1	2	3	4	5
4. Working with materials is an important part of technology.	1	2	3	4	5
5. Without electricity, there would be no technology.	1	2	3	4	5
6. Technology involves designing solutions to problems.	1	2	3	4	5
7. Most people have little to do with technology in their everyday lives.	1	2	3	4	5
8. In technology there are opportunities to design new products.	1	2	3	4	5
9. Two hundred years ago there was no technology.	1	2	3	4	5
10. Technology means inventing new ways of doing things.	1	2	3	4	5

Part B: What do you think about technology?

	STRONGLY AGREE	AGREE	CANT DECIDE	DISAGREE	STRONGLY DISAGREE
1. I am interested in technology.	1	2	3	4	5
2. Technology makes the world a better place to live in.	1	2	3	4	5
3. I would like to learn more about technology.	1	2	3	4	5
4. Technology has brought more good things than bad things.	1	2	3	4	5
5. I would like a career in technology later on.	1	2	3	4	5
6. It is worth spending money on technology.	1	2	3	4	5
7. I like to read books and magazines about technology.	1	2	3	4	5
8. Inventions in technology are doing more good than harm.	1	2	3	4	5
9. I would like to join a hobby club about technology.	1	2	3	4	5
10. Technology is needed by everybody.	1	2	3	4	5

This page is a supplement to a publication entitled *Technology Education in Science and Mathematics* authored by Jan Harding and Léonie Rennie and published by the national Key Centre for School Science and Mathematics at Curtin University of Technology, Perth, Australia.

WHAT TECHNOLOGY MEANS TO ME

Name ______________________ School ______________________ Class __________

Technology can mean different things to different people. When you read the word 'technology' what comes into your mind? What does technology involve?

Please tell us what technology means to you by writing about it, or by drawing a picture. You might like to do both.

Chapter 11

TEACHER-STUDENT RELATIONSHIPS IN SCIENCE AND MATHEMATICS CLASSES

Theo Wubbels
University of Utrecht, The Netherlands

Some teachers can get on better with their students than others. But do students learn more from teachers with whom they relate well? Although teachers often have distinct opinions about what is the best way in which to relate to students, different teachers' opinions vary markedly.

In the school staff room, it sometimes can be heard that students need a strict, disciplined environment in which to learn. "Students will not engage in learning activities themselves if teachers do not control their work and demand a lot of them. If there is too much freedom in class, students will be distracted from the real work; a cosy atmosphere will not promote student outcomes." Other teachers, however, advocate student responsibility for their learning and a pleasant classroom atmosphere for promoting student outcomes. "If students like the lessons and if there is a pleasant stimulating atmosphere, they will be stimulated to study, which is an important prerequisite for learning, and consequently they will thrive. It is more important to reward students for their efforts and the things that they do well than it is to correct their mistakes."

The language that teachers use makes their position clear. The teacher who thinks that students need tight rules will talk disapprovingly about a 'cosy classroom', whereas the one who takes the opposite position would talk about 'attractive, pleasant lessons'.

This chapter presents research findings about the interpersonal relationships between science and mathematics teachers and their students. It also sheds some light on other questions such as: What preferences do students have about their relationships with their teachers? How would teachers like to behave towards students? What teacher-student relationships are common in Australian science and mathematics classrooms?

This research is based on studies that used the *Questionnaire on Teacher Interaction (QTI)* to gather students' and teachers' perceptions of interpersonal teacher behaviour. Readers who are interested in the details of the studies or the methods used are referred to Brekelmans, Wubbels and Créton (1990), Wubbels, Brekelmans and Hooymayers (1991) or Wubbels, Créton and Hooymayers (1992). Below, we first describe this questionnaire, which is yet another example of the range of instruments available for assessing classroom environments (Fraser, 1989).

QUESTIONNAIRE ON TEACHER INTERACTION (QTI)

The Questionnaire on Teacher Interaction can be used to map students' and teachers' perceptions using a model for interpersonal teacher behaviour. In this model, teacher behaviour has a *Proximity Dimension* (Cooperation, C – Opposition, O) and an *Influence Dimension* (Dominance, D – Submission, S). These dimensions can be represented in a coordinate system divided into eight equal sections (see Figure 1). Every instance of interpersonal teacher behaviour can be placed within this system of axes. The closer the instances of behaviour are in the chart, the more closely they resemble each other.

The sectors are labelled DC, CD, etc. according to their position in the coordinate system. For example, the two sectors DC and CD are both characterised by Dominance and Cooperation. In the DC sector, however, the Dominance aspect prevails over the Cooperation aspect, whereas the adjacent sector CD includes behaviours of a more cooperative and less dominant character. To clarify the concepts covered by each sector, Figure 1 shows typical behaviours for each sector.

The long form of the Australian version of the Questionnaire on Teacher Interaction has 64 items

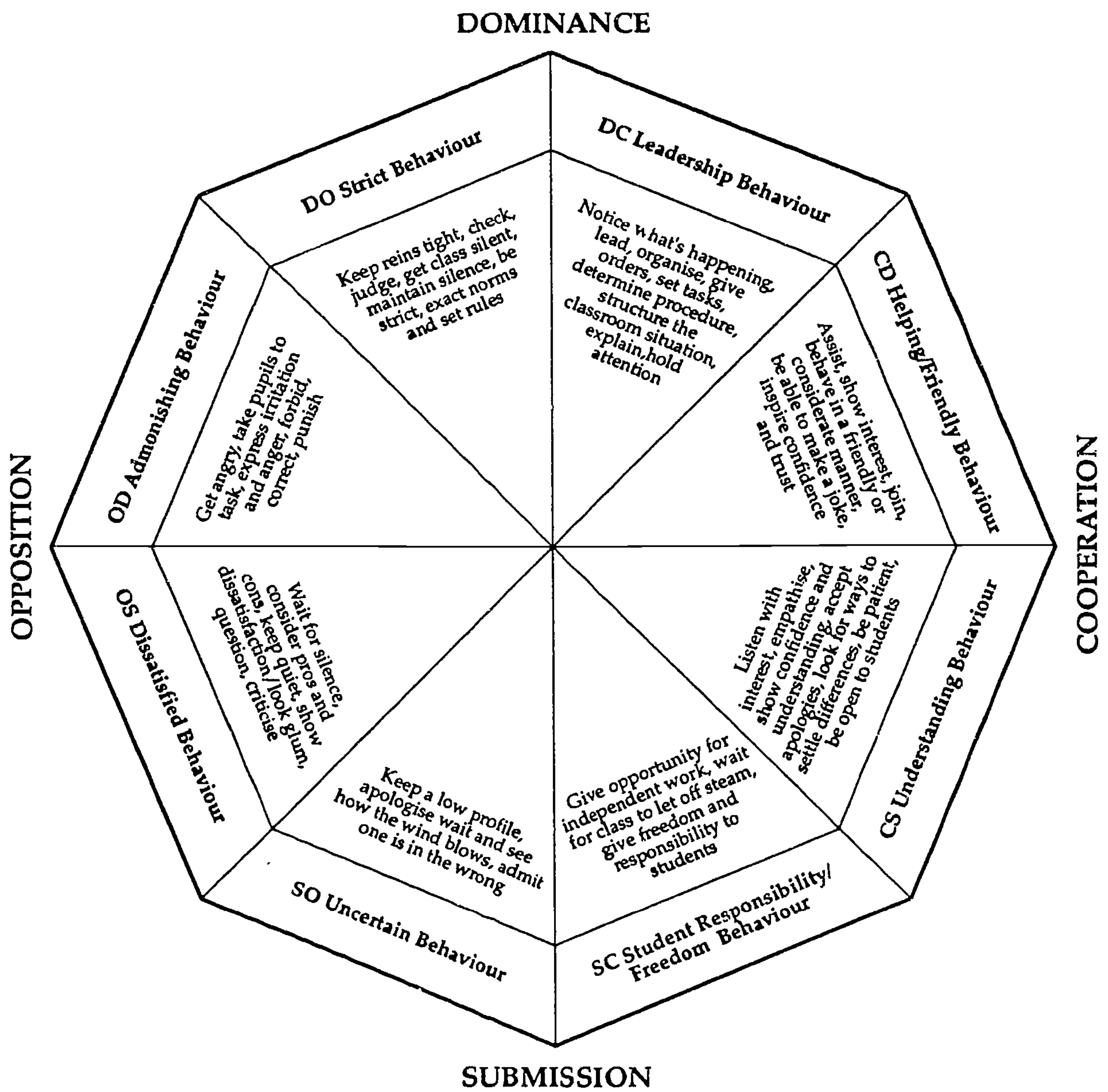

FIGURE 1: The Model for Interpersonal Teacher Behaviour

which are answered on a five-point scale. The items belong to eight scales, each consisting of eight items and corresponding to one of the eight sectors of the model. Examples of items are "This teacher is friendly" (CD) and "This teacher gets angry unexpectedly" (OD). The scores for each item within the same sector are added to obtain a total scale score. The higher the scale score, the more a teacher shows behaviours from that sector. Scale scores can be obtained for individual students, or can be combined to form the mean of all students in a class.

Information about the reliability of the questionnaire is presented in Appendix A for American, Australian and Dutch samples. It appears that the questionnaire has satisfactory reliability for all scales. For information about the validity of the QTI, we refer the reader to Wubbels and Levy (1991, 1993).

An economical short version of the QTI is available for use by teachers to gather information about students' (or the teacher's) perceptions of classes. This version has 48 items, six for every sector of the model of interpersonal teacher behaviour in Figure 1. A complete copy of this short version of the QTI, in a form that may be reproduced by teachers for use in their own classrooms, is provided as a Supplement.

In order to facilitate hand scoring, the items are arranged in cyclic order and in blocks of four. Items 1 to 24 in the Supplement assess the four scales called *Leadership* behaviour, *Understanding* behaviour, *Uncertain* behaviour and *Admonishing* behaviour, whereas Items 25 to 48 assess the scales *Helpful/Friendly* behaviour, *Student Responsibility and Freedom* behaviour, *Dissatisfied* behaviour and *Strict* behaviour.

In the top half of the questionnaire in the Supplement, the first item in every block assesses *Leadership* behaviour (Lea), the second one *Understanding* behaviour (Und), the third one *Uncertain* behaviour (Unc) and the fourth one *Admonishing* behaviour (Adm). The items in the lower half of the questionnaire in the Supplement are also grouped in blocks of four to assess *Helpful/Friendly* behaviour (HFr), *Student Responsibility and Freedom* behaviour (SRe), *Dissatisfied* behaviour (Dis) and *Strict* behaviour (Str).

The total score for a particular scale is simply the sum of the circled numbers for the six items belonging to that scale. A score of 3 is given for an omitted item or an invalidly answered item. For example, the Uncertain behaviour scale total is obtained by adding the scores given to items 3, 7, 11, 15, 19 and 23. Figure 2 gives an example of how the top half of the questionnaire (Items 1-24) was scored to obtain a total score of 19 for Leadership behaviour, 17 for Understanding behaviour, 4 for Uncertain behaviour and 7 for Admonishing behaviour.

A STUDY IN AUSTRALIA

We gathered data about Australian secondary school students' perceptions of the interpersonal behaviour of their science and mathematics teachers and perceptions of the behaviour of teachers that students consider to be their best teacher. Teachers were asked for their perceptions of their behaviour and of the behaviour that they would like to display (their ideal). A total of 792 students and their 46 teachers were involved in the study. The sample came from 46 typical Year 11 science and mathematics classes in Western Australia and Tasmania.

Actual Classroom Behaviour

In Figure 3, the average teachers' perceptions and the average students' perceptions of the teachers' behaviour in the classroom are shown graphically as profiles. These profiles for the Australian sample closely resemble those previously found in other countries. According to the teachers themselves and to their students, these teachers are rather high on Leadership, Friendly and Understanding behaviour. Uncertain, Dissatisfied and Admonishing behaviours are far less prominent.

However, there were some important differences between the teachers' and students' perceptions. Teachers on average had higher scores on Leadership, Helpful/Friendly and Understanding behaviours than their students.

Best Teachers and Teacher Ideals

The teachers' actual behaviour can be compared with the students' perceptions of their best teachers and the teachers' ideals (Figure 3). On average, the teachers do not reach their ideal. Also they differ from the best teachers as perceived by students. Best teachers, according to their students, are stronger leaders, more friendly and understanding and less uncertain, dissatisfied and admonishing

	Never Always	Teacher Use
1. This teacher talks enthusiastically about her/his subject.	0 1 2 3 (4)	Lea
2. This teacher trusts us.	0 1 2 (3) 4	Und
3. This teacher seems uncertain.	0 (1) 2 3 4	Unc
4. This teacher gets angry unexpectedly.	(0) 1 2 3 4	Adm
5. This teacher explains things clearly.	0 1 2 (3) 4	Lea
6. If we don't agree with this teacher, we can talk about it.	0 1 (2) 3 4	Und
7. This teacher is hesitant.	(0) 1 2 3 4	Unc
8. This teacher gets angry quickly.	0 (1) 2 3 4	Adm
9. This teacher holds our attention.	0 1 2 (3) 4	Lea
10. This teacher is willing to explain things again.	0 1 (2) 3 4	Und
11. This teacher acts as if she/he does not know what to do.	0 1 (2) 3 4	Unc
12. This teacher is too quick to correct us when we break a rule.	0 1 (2) 3 4	Adm
13. This teacher knows everything that goes on in the classroom.	0 1 (2) 3 4	Lea
14. If we have something to say, this teacher will listen.	0 1 2 (3) 4	Und
15. This teacher lets us boss her/him around.	0 (1) 2 3 4	Unc
16. This teacher is impatient.	0 (1) 2 3 4	Adm
17. This teacher is a good leader.	0 1 2 (3) 4	Lea
18. This teacher realises when we don't understand.	0 1 2 3 (4)	Und
19. This teacher is not sure what to do when we fool around.	(0) 1 2 3 4	Unc
20. It is easy to pick a fight with this teacher.	0 1 2 3 4	Adm
21. This teacher acts confidently.	0 1 2 3 (4)	Lea
22. This teacher is patient.	0 1 2 (3) 4	Und
23. It's easy to make a fool out of this teacher	(0) 1 2 3 4	Unc
24. This teacher is sarcastic.	0 (1) 2 3 4	Adm

For Teacher's Use Only: Lea 19 Und 17 Unc 4 Adm 7

FIGURE 2. Illustration of Hand Scoring Procedures for the Four Scales in the QTI Assessed by Items 1-24

than teachers on average. Best teachers also give students a little bit more responsibility.

The average teachers' perceptions of their behaviour take a position between the students' perceptions of actual behaviour and the teachers' ideal: the teachers on average think that they behave somewhat more according to their ideal than what their students think. So, they tend to see the learning environment a little more favourably than do their students.

A closer look at the ideals of individual teachers revealed two distinct types of ideals. In the first type, there is a lot of cooperative behaviour and a fair amount of leadership and strictness. The second type, however, shows a lot of behaviour that allows responsibility and freedom for the students in addition to cooperative behaviour. Among students' perceptions of best teachers, two similar types were found. Apparently some students prefer a strict teacher, whereas others prefer to have a lot of responsibility and freedom. From studies in The Netherlands, we know that by and large younger students prefer a teacher who holds the reins tight, whereas older students want to have more responsibility themselves.

A STUDY IN THE NETHERLANDS

We investigated relations between interpersonal teacher behaviour and student achievement and

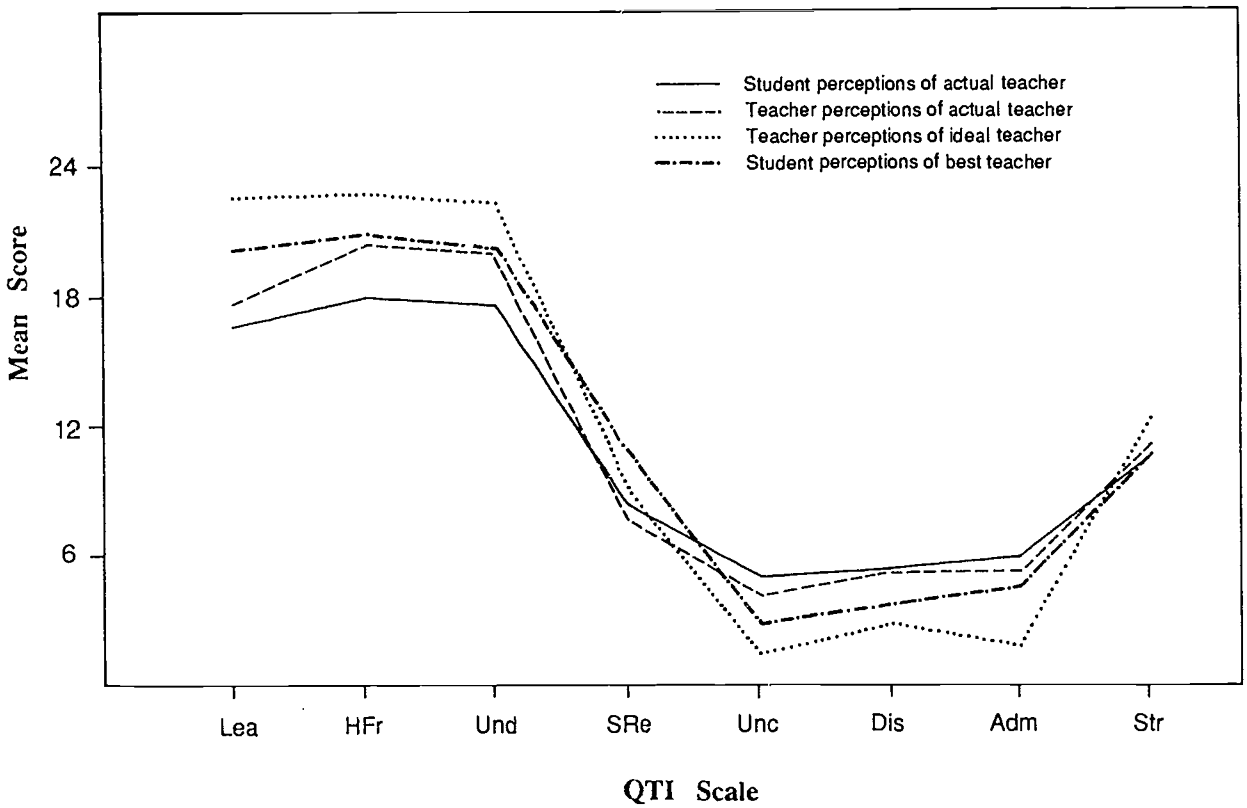

Figure 3. Profiles of Mean QTI Scores for Australian Teachers

attitudes in the Dutch option of the Second International Science Study. Teacher characteristics and opinions, teachers' perceptions of their interpersonal behaviour, and different curricula were incorporated into this study. Data were gathered in 66 Grade 9 physics classes. Student achievement was measured with a 23-item standardised and internationally developed test of physics subject matter. Attitudes were assessed with questionnaire items involving the students' experience of and motivation for physics and physics lessons.

Students' perceptions of interpersonal teacher behaviour appear to account for a large amount of the differences in outcomes between classes of the same ability level. The perceptions account for 70% of the variability in student achievement and 55% for attitude outcomes. So, at the class level, interpersonal teacher behaviour is an important factor related to student outcomes. The analyses also showed that the differences between the outcomes of teachers displaying different types of behaviours are far larger than differences in outcomes between teachers using different curricula or teachers of different age or teaching experience.

What interpersonal teacher behaviour is most favourable for student outcomes? When this question was addressed in several ways, the different analyses all pointed in the same direction.

Attitude Outcomes

The Cooperation scales of the model of interpersonal teacher behaviour (SC Student Responsibility and Freedom behaviour, CS Understanding behaviour, CD Helpful/Friendly behaviour, DC Leadership behaviour) are positively related to student attitudes. The more that teachers show behaviours from these sectors, the more positive are their students' attitudes. The Opposition scales (DO Strict behaviour, OD Admonishing behaviour, OS Dissatisfied behaviour, SO Uncertain behaviour) are all negatively related to attitudes. In terms of the model of interpersonal teacher behaviour, this means that students taught by teachers who show more than the 'average teacher' behaviour in the sectors on the right of the D-S axis and less in the sectors on the left of this axis on average viewed their physics lessons more positively.

Achievement Outcomes

Of the Dominance scales of the model, three scales (DO Strict behaviour, DC Leadership behaviour and CD Friendly behaviour) are positively related to student achievement, whereas three Submission scales (SC Student Responsibility behaviour, SO Uncertain behaviour and OS Dissatisfied behaviour) are negatively related to achievement.

The results presented are in keeping with those from other research, such as Haertel, Walberg and Haertel's (1981) finding that better achievement is found in classes perceived by students as having greater cohesiveness, satisfaction and goal-directedness and less disorganisation and friction.

We can relate the Australian students' perceptions of their best teachers and the teachers' perceptions of the ideal teacher to the results presented about Dutch students' outcomes. Looking at the average profile of the best and ideal teacher, we can expect that this kind of teacher will have superior student outcomes, because they have high scores on scales related positively to student outcomes and low scores on the negatively related scales.

CONCLUSION

The studies described in this chapter show that interpersonal teacher behaviour is an important aspect of the learning environment. It is strongly related to student outcomes. However, strong relations between the curriculum that a teacher uses and student outcomes were not found, thus suggesting that the importance of the curriculum factor in science teaching should not be overestimated. To improve student outcomes, the introduction of new curriculum materials probably has to be accompanied by appropriate changes in teacher behaviour.

Most Australian science and mathematics teachers in our sample displayed a lot of interpersonal behaviours that foster student outcomes. Emphasising behaviours from the leadership, friendly and understanding sectors of the model is likely to promote student outcomes. For uncertain, dissatisfied and admonishing behaviours, the relation is in the opposite direction. If teachers aim to promote both student achievement and attitudes, they are pulled in opposite directions by the conflicting demands of the sectors DO and SC. In order to promote higher achievement, teachers have to be stricter but, to promote better attitudes, they have to be less strict. The other six sectors of the model do not present conflicting demands.

REFERENCES

Brekelmans, J. M. G., Wubbels, Th., & Créton, H. A. (1990). A study of student perceptions of physics teacher behavior. *Journal of Research in Science Teaching, 27*, 335-350.

Fraser, B. J. (1986). *Classroom environment.* London, England: Croom Helm.

Fraser, B. J. (1989). *Assessing and improving classroom environment* (What Research Says to the Science and Mathematics Teacher, No. 2). Perth, Western Australia: National Key Centre for School Science and Mathematics, Curtin University of Technology.

Haertel, E. H., Walberg, H. J., & Haertel, G. D. (1981). Socio-psychological environments and learning: A quantitative synthesis. *British Educational Research Journal, 7*, 27-36.

Wubbels, Th., Brekelmans, M., & Hooymayers, H. (1991). Interpersonal teacher behavior in the classroom. In B. J. Fraser & H. J. Walberg (Eds.), *Educational environments: Evaluation, antecedents and consequences* (pp. 141-160). Oxford, England: Pergamon Press.

Wubbels, Th., Créton, H. A., & Hooymayers, H. P. (1992). Review of research on teacher communication styles with use of the Leary model. *Journal of Classroom Interaction, 27*, 1-12.

Wubbels, Th., & Levy, J. (1991). A comparison of interpersonal behavior of Dutch and American teachers. *International Journal of Intercultural Relations, 15*, 1-18.

Wubbels, Th., & Levy, J. (Eds.). (1993). *Do you know what you look like: Interpersonal relationships in education.* London, England: Falmer Press.

APPENDIX A

Reliability (Alpha Coefficient) for QTI Scales for Students and Teachers in Three Countries

QTI Scale	Reliability: Students USA	Students Australia	Students The Netherlands	Teachers USA	Teachers Australia	Teachers The Netherlands
DC Leadership	0.80	0.83	0.83	0.75	0.74	0.81
CD Helpful/friendly	0.88	0.85	0.90	0.74	0.82	0.78
CS Understanding	0.88	0.82	0.90	0.76	0.78	0.83
SC Student responsibility/freedom	0.76	0.68	0.74	0.82	0.60	0.72
SO Uncertain	0.79	0.78	0.79	0.79	0.78	0.83
OS Dissatisfied	0.83	0.78	0.86	0.75	0.62	0.83
OD Admonishing	0.84	0.80	0.81	0.81	0.67	0.71
DO Strict	0.80	0.72	0.78	0.84	0.78	0.61
Sample Size	1 606	792	1 105	66	46	66

SUPPLEMENT

STUDENT QUESTIONNAIRE

This questionnaire asks you to describe the behaviour of your teacher. This is NOT a test. Your opinion is what is wanted.

This questionnaire has 48 sentences about the teacher. For each sentence, circle the number corresponding to your response. For example:

	Never				Always
This teacher expresses himself/herself clearly.	0	1	2	3	4

If you think that your teacher always expresses himself/herself clearly, circle the 4. If you think your teacher never expresses himself/herself clearly, circle the 0. You also can choose the numbers 1, 2 and 3 which are in between. If you want to change your answer, cross it out and circle a new number. Thank you for your cooperation.

Don't forget to write the name of the teacher and other details at the top of the reverse side of this page.

This page is a supplement to a publication entitled *Teacher and Student Relationships in Science and Mathematics Classes* authored by Theo Wubbels and published by the national Key Centre for School Science and Mathematics at Curtin University of Technology.

Teacher's Name ____________ Class ______ School ____________

	Never				Always	Teacher Use
1. This teacher talks enthusiastically about her/his subject.	0	1	2	3	4	Lea
2. This teacher trusts us.	0	1	2	3	4	Und
3. This teacher seems uncertain.	0	1	2	3	4	Unc
4. This teacher gets angry unexpectedly.	0	1	2	3	4	Adm
5. This teacher explains things clearly.	0	1	2	3	4	Lea
6. If we don't agree with this teacher, we can talk about it.	0	1	2	3	4	Und
7. This teacher is hesitant.	0	1	2	3	4	Unc
8. This teacher gets angry quickly.	0	1	2	3	4	Adm
9. This teacher holds our attention.	0	1	2	3	4	Lea
10. This teacher is willing to explain things again.	0	1	2	3	4	Und
11. This teacher acts as if she/he does not know what to do.	0	1	2	3	4	Unc
12. This teacher is too quick to correct us when we break a rule.	0	1	2	3	4	Adm
13. This teacher knows everything that goes on in the classroom.	0	1	2	3	4	Lea
14. If we have something to say, this teacher will listen.	0	1	2	3	4	Und
15. This teacher lets us boss her/him around.	0	1	2	3	4	Unc
16. This teacher is impatient.	0	1	2	3	4	Adm
17. This teacher is a good leader.	0	1	2	3	4	Lea
18. This teacher realises when we don't understand.	0	1	2	3	4	Und
19. This teacher is not sure what to do when we fool around.	0	1	2	3	4	Unc
20. It is easy to pick a fight with this teacher.	0	1	2	3	4	Adm
21. This teacher acts confidently.	0	1	2	3	4	Lea
22. This teacher is patient.	0	1	2	3	4	Und
23. It's easy to make a fool out of this teacher	0	1	2	3	4	Unc
24. This teacher is sarcastic.	0	1	2	3	4	Adm
25. This teacher helps us with our work.	0	1	2	3	4	HFr
26. We can decide some things in this teacher's class.	0	1	2	3	4	SRe
27. This teacher thinks that we cheat.	0	1	2	3	4	Dis
28. This teacher is strict.	0	1	2	3	4	Str
29. This teacher is friendly.	0	1	2	3	4	HFr
30. We can influence this teacher.	0	1	2	3	4	SRe
31. This teacher thinks that we don't know anything.	0	1	2	3	4	Dis
32. We have to be silent in this teacher's class.	0	1	2	3	4	Str
33. This teacher is someone we can depend on.	0	1	2	3	4	HFr
34. This teacher lets us fool around in class.	0	1	2	3	4	SRe
35. This teacher puts us down.	0	1	2	3	4	Dis
36. This teacher's tests are hard.	0	1	2	3	4	Str
37. This teacher has a sense of humour.	0	1	2	3	4	HFr
38. This teacher lets us get away with a lot in class.	0	1	2	3	4	SRe
39. This teacher thinks that we can't do things well.	0	1	2	3	4	Dis
40. This teacher's standards are very high.	0	1	2	3	4	Str
41. This teacher can take a joke.	0	1	2	3	4	HFr
42. This teacher gives us a lot of free time in class.	0	1	2	3	4	SRe
43. This teacher seems dissatisfied.	0	1	2	3	4	Dis
44. This teacher is severe when marking papers.	0	1	2	3	4	Str
45. This teacher's class is pleasant.	0	1	2	3	4	HFr
46. This teacher is lenient.	0	1	2	3	4	SRe
47. This teacher is suspicious.	0	1	2	3	4	Dis
48. We are afraid of this teacher	0	1	2	3	4	Str

For Teacher's Use Only: Lea ___ Und ___ Unc ___ Adm ___ HFr ___ SRe ___ Dis ___ Str ___

Chapter 12

SECONDARY SCIENCE AND MATHEMATICS ENROLMENT TRENDS

John A. Malone, John R. de Laeter
Curtin University of Technology, Western Australia

John Dekkers
University of Central Queensland

Most science and mathematics teachers throughout Australia would be aware of changes in the enrolment patterns of upper secondary students over the past decade which are now affecting both the size of their classes and the balance of male and female students. However the *magnitude* of these changes could well have escaped the attention of many teachers. Enrolment patterns in science and mathematics in Australia currently are of national concern because of the low overall participation rates in these subjects and because of the gender (im)balance in enrolment numbers. On the other hand, the number of students enrolling in certain science and mathematics subjects at the upper school level is encouraging.

The overall enrolment patterns are encouraging because they reflect a response to the specific initiatives of Australian curriculum developers to introduce programs that are more relevant to students than they have been in the past, and which enable students to cope with, and contribute to, a society that is becoming increasingly technologically oriented. Every State and Territory in Australia has introduced new mathematics and science curricula which have been designed to provide relevant subjects focused upon the various levels of student ability and interest (Australian Science and Technology Council, 1987).

We have collected the most comprehensive data base currently available relating to enrolment patterns in upper school science and mathematics in Australia (Dekkers, de Laeter & Malone, 1991). These data include most of the enrolment statistics for each State and Territory since 1970, along with all data since 1976 in the Year 12 subjects of biology, chemistry, physics, geology and alternative science. In computing science and mathematics, most State and Territory statistics since 1970 are included, along with all data since 1980. Trends evident in these data are startling.

Figure 1 compares the total Year 12 student enrolment with the total Year 12 science and mathematics subject enrolments for both Public Examination and School Assessed Subjects for the period 1980-1990. As Australian teachers know, the vast majority of students – over 90% – take Public Examination Subjects (PES) as these meet entry requirements and/or selection prerequisite for entry into university. School Assessed Subjects (SAS) might not be as familiar to teachers in some Australian states as are PES. They are designed and assessed by the school at which a student is enrolled, and are generally intended for students who seek to study science/mathematics at school, but who do not intend to pursue university studies. In 1979, there were no SAS enrolments for science and mathematics subjects, but such subjects were progressively introduced into schools throughout Australia during the 1980s. The response to them has been significant – in 1990, SAS represented 6% of science and 17% of mathematics and computing enrolments.

Despite the fact that the national retention rate from Year 8 to Year 12 increased over 25% between 1980 and 1990 and is higher for girls than boys, this is not reflected in the enrolments in most science and mathematics subjects depicted in Figure 1. In biology and in the less rigorous mathematics units, female enrolments have increased over the years to the point where girls now outnumber boys. But, in the physical sciences and most difficult mathematics subjects, there remains a sharp disparity between male and female enrolments, even though some improvement has occurred over the last decade. In 1990, for example, 29% of Year 12 physics students were girls (compared with

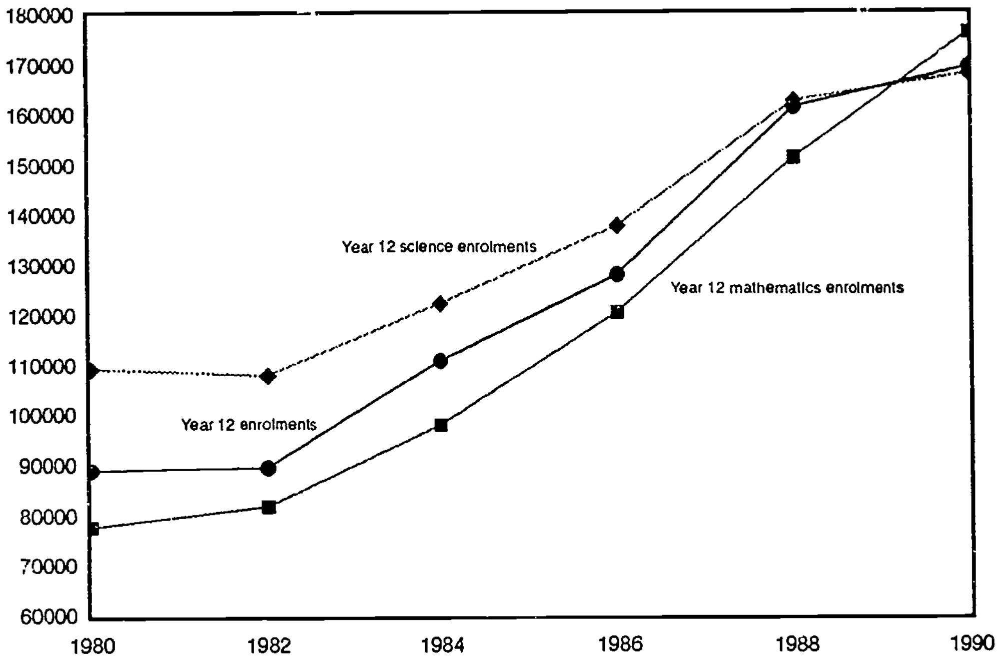

FIGURE 1. Year 12 Science, Mathematics and Total Enrolments (1980-1990)

25% in 1979), 43% of chemistry students were girls (compared with 35% in 1979) and approximately 38% of enrolments in the more difficult mathematics subjects were girls (compared with about 30% in 1979). For the newer alternative science subjects (including Physical Science, General Science, Environmental Science), the proportion of girls enrolled in 1990 was approximately 42%, which is higher than for most of the traditional science subjects.

From Figure 1 it is clear that science subject enrolments have not kept pace with the growth in Year 12 student enrolments. Overall growth in science subject enrolments can be attributed largely to increases in science SAS enrolments. For mathematics, however, a consistent growth in subject enrolments since 1982 has paralleled the growth in Year 12 student enrolments. This is in part due to increases in the range of mathematics PES and SAS offerings from which students can choose.

SCIENCE ENROLMENT TRENDS

Enrolment trends for science subjects in Australia over the past three decades are well documented. Dow (1971), who surveyed science enrolment patterns at the upper secondary school level for the period 1960-1969, concluded that the proportion of students taking chemistry and physics in all States was decreasing. However, the decline was more than outweighed by the increasing proportion of students studying biology. The major point with data of this kind is that the *new* students (i.e., Year 12 students who in earlier times would *not* have proceeded to Year 12) are not likely to take physics and chemistry, which are recognised as being better suited for the more academically able students. Also, because the size of the school age population (Year 8) increased only about 12% since 1970, the *proportion* of students enrolling in science was bound to go down.

Details of Year 12 science enrolments in Australia for the period 1976 to 1990 are illustrated in Figure 2. The trends in the data can be summarised as follows:

- More students enrol in biology than in any of the other science disciplines. Female enrolments in biology throughout the last 10 years outnumber male enrolments by a factor of approximately two.
- Chemistry enrolments have gradually increased during the 1980s. Female enrolments currently account for approximately 43% of total chemistry enrolments.

- Enrolments in physics closely parallel chemistry. In 1990, females accounted for approximately 29% of the total physics enrolment.
- Geology has the smallest enrolment for the science disciplines. Enrolments were relatively static during the 1980s, although there was an overall drop between 1976 and 1990.
- Enrolments in Alternative Science have increased more sharply than for any of the other science areas. Alternative science subjects include Physical Science, General Science, Environmental Science and Agriculture. In 1990, females accounted for approximately 42% of the total alternative science enrolments.

For the period 1976 to 1990, Year 12 enrolments increased by approximately 95%. The comparable increases for biology, chemistry and physics were 30%, 64% and 51%, respectively, whereas geology enrolments actually declined by 34%.

MATHEMATICS ENROLMENT TRENDS

Public Examination mathematics enrolments in Year 12 for the period 1975-1990, together with SAS enrolments for 1985-1990, are shown in Figure 3. Although there was a slight reduction in mathematics enrolments in Year 12 between 1979 and 1981, the numbers have grown steadily since then. The total number of students in Year 12 studying a mathematics subject also has grown since 1982 and the pattern of growth roughly has paralleled that for the total Year 12 population. The pool of students with at least one mathematics subject has increased significantly after suffering a decline over 1980 and 1981.

Until 1985, the pool of Australian students taking a mathematics subject generally was made up of those studying the most rigorous, or 'advanced', mathematics subjects and those taking other levels of mathematics subjects which could be classified as 'ordinary' level subjects. Since 1985, the presence of School Assessed Subjects has had a large effect on enrolments in advanced level mathematics subjects, including those subjects which provide the grounding for extensive study in mathematics or related areas in higher education. 'Advanced' level mathematics subjects at the Year 12 level are defined as those which lead on to tertiary courses requiring rigorous secondary mathematics as a prerequisite – engineering and pure mathematics, for example – whilst 'ordinary' level mathematics subjects are defined as comprising all other types of mathematics courses taken at that level. The

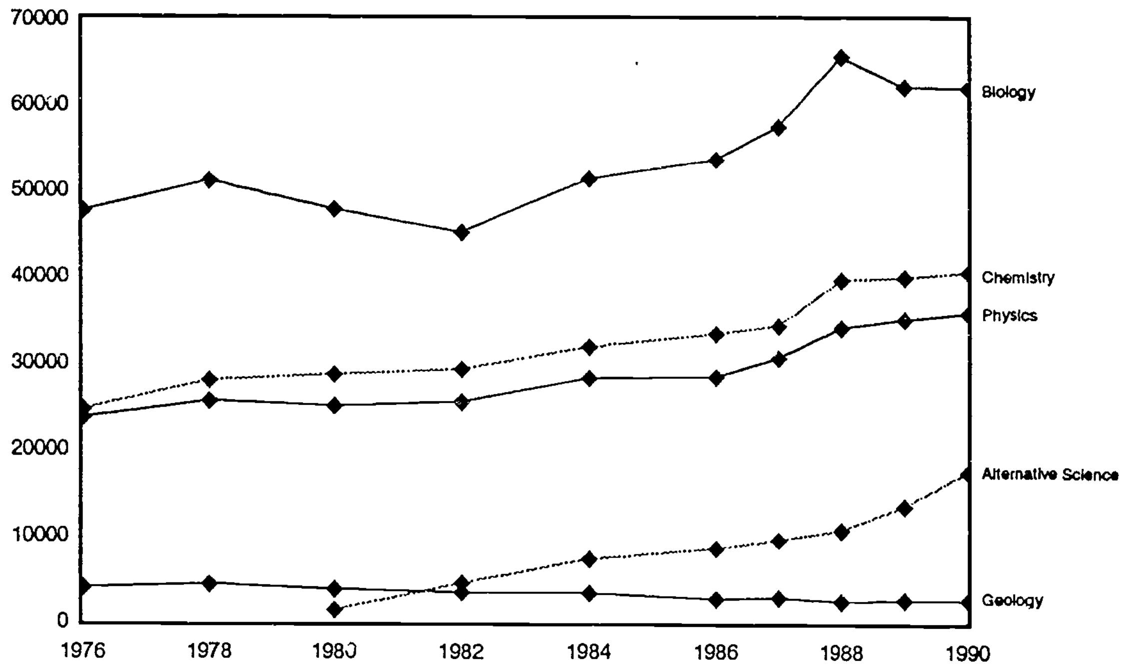

FIGURE 2. Year 12 Science Enrolments in Australia (1976-1990)

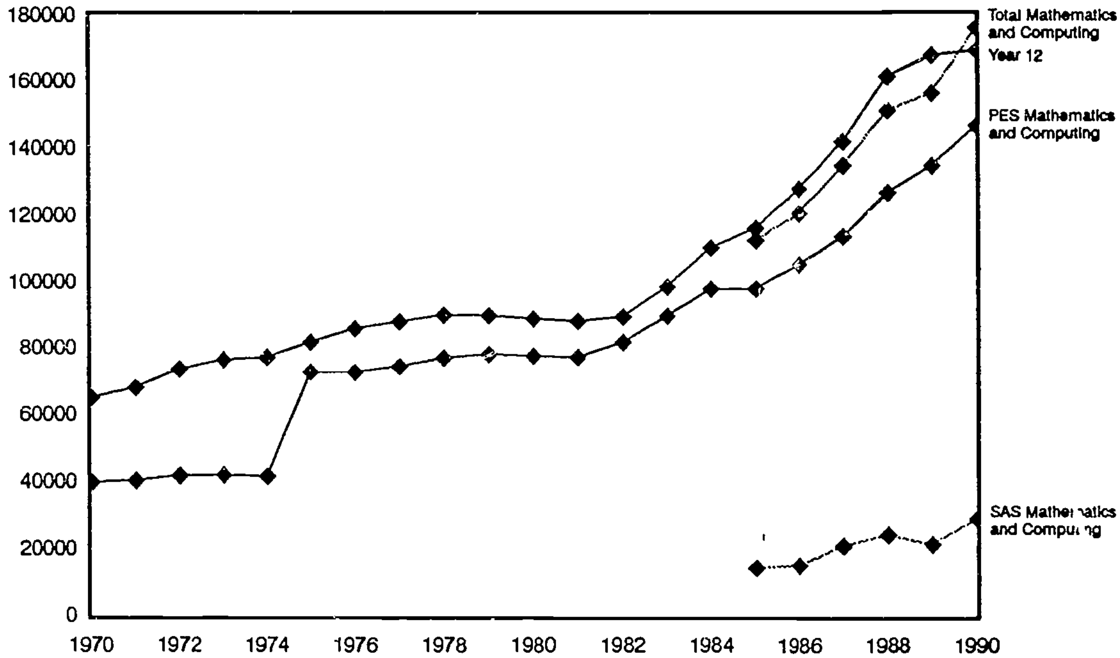

FIGURE 3. Year 12 Mathematics and Computing Enrolments in Australia (1970-1990)

'ordinary' level group is made up of those Year 12 subjects in mathematics which clearly are designed as 'consumer' type courses and which are not suitable as a preparation for any further study in mathematics in higher education.

A significant feature of the trends is that there has been only a marginal growth over the 10-year period in the total number of Year 12 students taking an advanced mathematics subject, whilst since 1982 there has been a substantial growth in the number with an ordinary level mathematics subject.

For example, in Western Australia, the proportion of the Year 12 population with advanced mathematics decreased approximately 19% from 54% in 1976 to 35% in 1991 (Alguire, 1992; Dekkers, de Laeter & Malone,1991). The proportion in ordinary mathematics increased from 22% in 1976 to 65% in 1991 – a 43% increase overall. This change can be attributed to the wider range of subjects offered in the ordinary level mathematics courses as well as the increased participation of females in Year 12.

Thus the number of students with a mathematics background suitable for higher education studies in the science, technology and mathematics areas has remained relatively constant despite the increase in the number of students studying mathematics in Year 12. Nationally the proportion of the Year 12 population with Year 12 advanced mathematics decreased approximately 5% from 22% in 1976 to 17% in 1990.

Unlike the science data in Figure 2, enrolment trends for both Year 12 enrolments and mathematics enrolments are very similar (Figure 3). The proportion of students studying SAS mathematics and computing increased from 13% in 1985 to 17% in 1990. This strong growth in enrolments possibly explains the view, held in the late 1980s by many mathematics teachers and educators, that almost every student at the Year 12 level in Australia was studying some type of mathematics unit. Although there appears to be almost as many mathematics and computing enrolments as there are Year 12 enrolments, it should be remembered that students may choose to study more than one mathematics unit.

In summary, participation in mathematics over the last decade in Australia is characterised by a number of features:

1. There has been an overall increase in enrolments and retention at Year 12, which has resulted in an increased pool of students, especially

females, who study a mathematics subject in their Year 12 course.

2. The enrolment growth has been more pronounced in ordinary level mathematics subjects than in advanced subjects.

3. The participation rate in advanced mathematics has decreased over the last decade.

4. The participation rate in ordinary level mathematics courses – that is, those subjects which are not usually regarded as an adequate form of preparation for higher education study in mathematics, technology and science – is increasing.

5. The proportion of females taking up advanced mathematics since 1976 has increased. Females now outnumber males in the ordinary level mathematics subjects, while males outnumber females in the advanced level mathematics subjects.

6. The intakes in Year 8 have been decreasing steadily since 1985. A corresponding decrease in the pool of well-qualified students with Year 12 advanced mathematics is likely to occur despite the general continuing increase in retention to Year 12.

WHAT CAN WE EXPECT AND WHY?

Compared to two decades ago, the Year 12 student body in Australia now represents a wider range of abilities and aspirations than ever before. The Dekkers, de Laeter and Malone data (1991) indicate that the recent increase in the Year 12 population is likely to taper off as the Year 8 enrolments drop. However, the large age cohort, coupled with the trends in retentivity, should have a significant impact on the number of students entering Year 12 in the immediate future. Consequently, this increasing pool of students presents substantial flexibility for both teachers and employers in mathematical, technological and scientific areas assuming that the 'quality' of those who complete Year 12 does not decline. Yet evidence presented by several researchers (Dekkers, de Laeter & Malone, 1991; Jones, 1988a, 1988b) suggests that this quality *has* declined in that there has been in fact a 'swing' away from advanced mathematics, physics and chemistry in the senior secondary school years from the more rigorous mathematics and science units available to the less rigorous ones in each Australian State. The authors believe that such data can be misinterpreted. The truth is that the population has changed. Although a smaller proportion of Year 12 students is studying the more rigorous science and mathematics units, enrolments in biology, other science units and the ordinary mathematics subjects are most encouraging.

The changing nature of enrolments in mathematics and science at the senior secondary school level can be attributed to the interplay between a number of factors, including:

- the increase in the number of mathematics and science subjects now available in most States;
- the relative difficulty of these subjects;
- interest and enjoyment in these subjects;
- the career relevance of the subjects;
- the changing mix of the student population.

Also, the increased tendency for females to remain at school until Year 12 can be attributed to a number of interrelated factors, including:

- greater acceptance of females in professions that previously have been male-dominated, particularly those that require a university education;
- the increase in youth unemployment;
- a concerted effort by professional associations and Government at both State and Federal levels to encourage females to complete school to Year 12.

It is evident from the data presented in this issue that many upper secondary school students do not study school science and mathematics. A number of studies has identified reasons for this situation (Dekkers & de Laeter, 1983; Queensland Board of Secondary School Studies, 1985; Wood & de Laeter, 1986):

- an increase in the choice of non-science and mathematics subjects;
- the perceived relative difficulty of science and mathematics;

- a lack of interest and enjoyment by students studying science and mathematics;
- career relevance of science and mathematics;
- peer pressure, parental influence and advice given by school counsellors and teachers.

WHAT CAN BE DONE?

There is a growing body of opinion that relevant aspects of science should be reinstated in the curriculum, even if it means that students might not cover the same depth of theoretical and mathematical content. A greater emphasis on laboratory work also would be desirable in many cases. The trends in mathematics parallel those in science, and the influence of female students on these trends has been significant because of the greatly increased retentivity of females over the past 15 years. Specialist mathematics and science subjects traditionally have attracted a higher proportion of male students, in part because more males have undertaken careers in engineering and the physical sciences.

The increasing attraction of commerce and business-oriented courses (including information technology) at the tertiary level in recent years has been a contributing factor in the sense that these courses today do not require the most rigorous mathematics and science subjects. Many students with the capacity to study the more rigorous mathematics and science subjects are diverted away from such study by a variety of influences, not least of which is peer-group pressure. The teacher has a role to play in countering these influences.

Authorities increasingly are concerned at the paucity in the numbe of young people now studying advanced mathematics and science at the upper secondary school level. This concern has been fuelled by our economic difficulties and the importance of technological development as one means of reversing present economic trends. While we do not believe that the enrolment situation is as depressing as sometimes depicted, we acknowledge that the immediate challenge for teachers and educators is to facilitate and help devise strategies that will increase participation in science and mathematics, particularly physics, chemistry and the more advanced mathematics subjects. There also must be a more concerted effort to instil an understanding in the Australian community of the social significance of technological development and processes in an industrial society. While the latter is not solely the teacher's responsibility, he or she can go a long way in providing a sound background in science and mathematics education at the secondary level – an important component in any plan to enable Australia to compete successfully in an increasingly technological society – while at the same time addressing both the cultural and professional needs of students.

There is also a need to increase the scientific and mathematical ability of the majority of the nation's secondary school students, and the onus for this seems to fall squarely on the shoulders of the teacher. It implies the need to cater in a more appropriate manner for the wider range of abilities which now exist in the upper secondary school. The evidence presented in this publication suggests that this latter objective is being accomplished to an increasing extent, and that this trend is likely to continue. If Australia is to sustain its position as a developed country, it is essential that young people should be acquainted with the variety of careers in mathematics, science and technology at professional and paraprofessional levels, and also with the need for a skilled technological workforce within the country to meet the challenges of the future.

REFERENCES

Alguire, H. (1992). More students opt for maths. *Australian and New Zealand Association for the Advancement of Science News, 1*(1), 3.

Australian Science and Technology Council. (1987). *Education and national needs.* Canberra, Australian Capital Territory: Commonwealth Government Printing Service.

Dekkers, J., de Laeter, J. R., & Malone, J. A. (1991). *Upper secondary school science and mathematics enrolment patterns in Australia, 1970-1989.* Perth, Western Australia: National Key Centre for School Science and Mathematics, Curtin University of Technology.

Dekkers, J., & de Laeter, J. (1983). Female and male school science enrolments 1970-1979. *Search, 14*, 140-145.

Dow, K.L. (1971). *Teaching science in Australian schools.* Melbourne, Victoria: Melbourne University Press.

Jones, W. (1988a). *Entry to engineering technology and science in higher education* (ACER Occasional Paper No. 20). Hawthorn, Victoria: Australian Council for Educational Research.

Jones, W. (1988b). *Secondary school mathematics and technological careers* (ACER Research Monograph No. 32). Hawthorn, Victoria: Australian Council for Educational Research.

Queensland Board of Teacher Education. (1985). *Teachers for mathematics and science* (Report of Working Party). Queensland: Board of Secondary School Studies.

Wood, D., & de Laeter, J. (1986). Why students choose physics. *The Australian Physicist, 23*, 286-288.