Choosing or avoiding mathematics at the upper-secondary school level: some significant factors

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Over 1995 and 1996, the researchers conducted a study of the factors which influence Australian students' selection or non-selection of mathematics subjects at the upper school level. Some 6 000 students from Western Australia, Queensland and Victoria responded to a survey seeking to determine such factors. This paper describes the outcomes of the survey and suggests that students' cognitive style orientations have a significant role to play in the subject selection process.

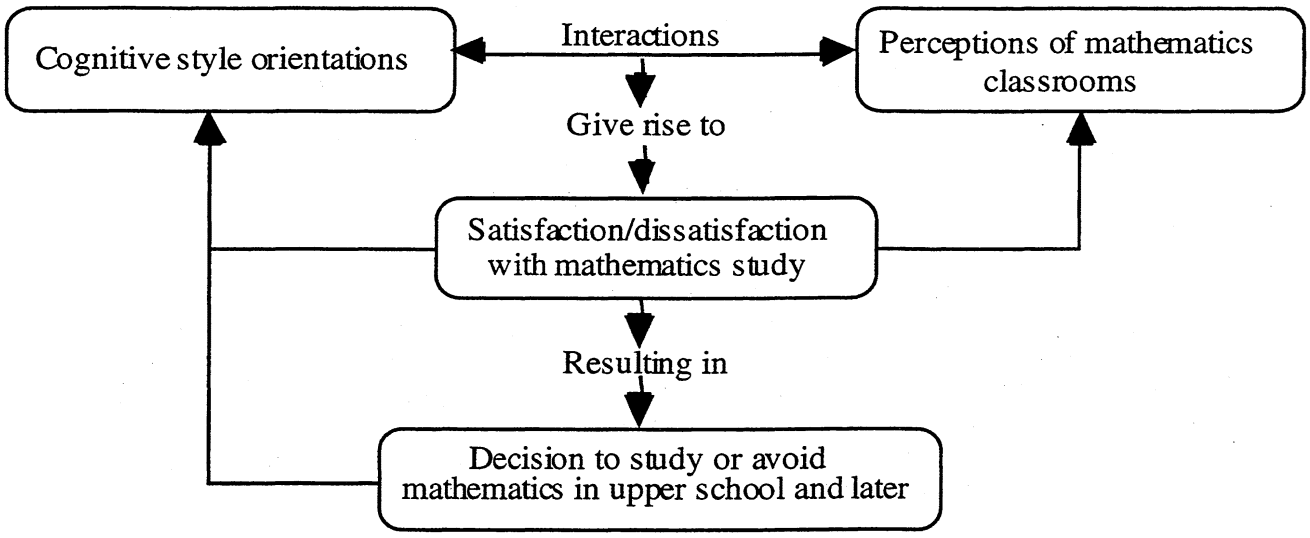
Introduction

The Report entitled *Science and Technology Education: Foundations for the Future* (Brennan, 1994) urged researchers to investigate the decision-making processes that turn students 'onto' or 'off' science and mathematics as a further education or career option. Consequently, this study aimed to investigate the sociological and psychological factors influencing students' choice of mathematics subjects. A literature review indicated that factors which do appear to contribute to students' decisions about their involvement with mathematics include organisational reasons (e.g. school timetable arrangements); personal or individual (e.g. self esteem); confidence with mathematics (e.g. anxiety), perceptions of mathematics as lacking in social relevance and lacking in satisfying career prospects. Another set of contributing factors possibly involves students' cognitive style orientations – that is, those psychological attributes accounting for students' attitudes towards classroom experiences. These latter factors provided a principal focus for the study, for they are potentially manipulable by educators whereas many of the other factors are not (a statement based on the considerable attention given to those other factors in the past, with few discernible results).

The democratic nature of Australian education systems allows students and parents to make decisions about subject choice in secondary education, an arrangement which has provided a mechanism for enabling academically able students to opt out of further study in courses such as advanced science and mathematics. Although there has been a national increase in participation rates for post-compulsory education, there has not been a proportional increase in participation in courses of advanced mathematics and science, and the drop-out in these subjects is now regarded as critical (Malone, 1993; Dekkers, de Laeter & Malone, 1991, 1993; Secondary Education Authority, 1995; de Laeter & Dekkers, 1996; The *Australian*, Feb, 1997).

Apart from the Brennan Report, Australia-wide concern has been steadily growing about this low level of participation in secondary school courses leading to further education and careers in mathematics and science (Brennan, 1994; The *Herald Sun*, Nov, 1996; *The Age*, Jan 1997; The *Australian*, Feb, 1997; *Campus Review*, Feb, 1997). At the heart of these concerns is the desire to ensure that those students who are most capable in mathematics and science continue with these subjects and find themselves well placed for careers in these fields in later life. To this end, this study sought to determine those factors which facilitate this process in mathematics. The study was based upon the assumption that students possess cognitive style orientations which interact with the way they perceive

mathematics classroom environments and hence determine particular levels of satisfaction with the subject. This satisfaction, in turn, is related to students' decisions to continue with (or reject) mathematics as an area of study. The simple non-causative, non-linear model below illustrates relationships between a number of variables exercising reciprocal influences.



Students' cognitive style orientations are taken to be psychologically based attributes which underpin their attitudes towards interactions with others, the way they structure knowledge and their approaches to problem solving and self discipline (Denham, 1994, 1995). In this sense, they are associated with particular needs in students which can be either satisfied, to varying degrees, by the way the students perceive their classrooms – in this case their mathematics classrooms. Many of the other factors mentioned earlier which are known to influence students' subject choice continue to be the subject of investigation, but have failed to counter the downward spiral in enrolments and were not considered in great detail in this study. Rather, the study addressed cognitive factors that have not been considered before in the context of student subject and career choice. It was anticipated that the study's outcomes would have implications for teaching and learning approaches and for curriculum development in terms of students' cognitive style orientations.

Theoretical Background

In many Australian secondary schools, the career and subject choice counselling process has been formalised through the introduction of career and vocational education courses. Science subject selection is now part of a structured counselling program based upon career education theories and implemented by specialist school staff. Counselling programs encourage students to identify their personal needs and to reflect upon the extent to which these are satisfied in particular subject areas or may be realised in particular vocations. There are two implications here for mathematics education. Firstly, mathematics curricula and teaching methodologies need to provide students with personally satisfying experiences. If this does not occur, capable students may select other subjects.

Secondly, in order to influence subject choice decisions, mathematics educators need to understand the theoretical grounding and counselling procedures of career education. This knowledge needs to be reflected in mathematics curriculum design and pedagogy. It is strategically important for classroom practitioners and researchers to thoroughly understand how students make subject choice decisions.

Comprehensive theoretical frameworks which explain career and subject choice decision-making have been developed within the discipline of career education (Osipow, 1990; Herr and Cramer, 1992). Theoretical approaches include the matching of human traits and factors, studying the decision making process itself, the application of sociological constructs, the influence of psychological attributes and needs, and the developmental nature

of an individual's ability to make informed career decisions (Herr and Cramer, 1992). Another approach to understanding subject choice is based upon Holland's (1973) theory of occupational choice. This proposes that a choice of occupation should ensure a match between personal characteristics, for example personality, attitudes, ability and interests, and the rewards and experiences coming from engaging in the occupation (Holland, 1973, Baker, 1985; Smithers and Hill, 1989; Ramsden and Ramsden, 1990; Malone and Cavanagh, 1995, Malone and Cavanagh, In press).

The proposed study set out to examine, among other things, the ways in which cognitive style orientations are influential in turning students 'onto' or 'off' science.

Goals of the study

The aims of the study were to:

1. develop a questionnaire to investigate those organisational, socio-cultural, personal and cognitive style orientations which influence students' decisions to study or avoid mathematics at the upper school level,
2. use this information to conduct case studies with students to probe further the reasons for their decision to study or avoid mathematics, and
3. determine the implications of the findings for teachers, school administrators, curriculum developers, students and teacher-training staff.

Methodology

The entire study extended over 1995-1996.

- A questionnaire was developed consisting of items corresponding to the factors of interest mentioned in goal 1 above. As the survey was to be administered to students in Western Australia, Queensland and Victoria (based on the location of the researchers and capitalising on the variety of mathematics curricula and range of mathematics units available in each state, so enhancing the study's 'national' flavour), three versions of the questionnaire were prepared, each taking into account subject titles and other matters idiosyncratic to the different states.
- The questionnaire was used to gather information from a total of 5 817 Year 11 and Year 12 students in public, independent and catholic schools, chosen by means of a proportionate sampling technique, in each of the three states during 1995.
- The second phase of the study (1996) involved developing 21 case studies of individual students chosen from the same schools in the three Australian states (7 per state) in order to probe further their reasons for choosing or avoiding mathematics. This case study data is still being analysed. Emerging insights are discussed later in this paper.

Findings

The Questionnaire (general items):

The data were analysed for themes and issues which significantly contributed to students choosing or avoiding of mathematics in the upper school. Basic statistics such as frequency counts, proportions and cross-tabulations were based upon weighted data, and univariate and bivariate statistics were used to provide a description of the characteristics of the sample and to facilitate an initial exploration of the relationship between the variables. The analysis suggested some strong links between students' decisions to choose or avoid mathematics and the independent variables described below. The dependent variable for the analysis was the mathematics level chosen by students, categories being: High Level Mathematics (the most rigorous); Mid Level Mathematics; Low Level Mathematics (unacceptable for tertiary entrance), and No Mathematics Taken.
Analysis of the questionnaire data suggests strong links between students' decision to choose or avoid mathematics and their

- perceived ability and experiences with mathematics in the primary and early secondary school

- confidence in, and attitudes towards mathematics
- school type
- friends who are studying mathematics, and influential others
- views on the need to possess natural ability in mathematics
- views on the need for mathematics in the career they hope to pursue.

Perceived Ability: A student's perceived ability in mathematics had the strongest effect in him/her choosing or avoiding mathematics. Of major interest is the fact that 35% of students perceived themselves as being excellent when they were in primary mathematics, 19% perceived themselves as being excellent in lower secondary mathematics and only 9% rated themselves as currently being excellent in mathematics. In this sample, 71% of the students had taken mid to high level mathematics. Of those, many indicated that their current ability was only reasonable.

Student Attitudes: Of the variables which make up the students' attitudes, confidence in studying mathematics has the strongest effect on choosing or avoiding the subject and is most strongly correlated with the students' perceived ability (significant at the 0.05 level of confidence). Analysis indicates a weak relationship between a student's enjoyment of mathematics and the mathematics level taken, and that a student's career aspirations are a better indicator as to the mathematics level chosen in upper school. Seventy-nine percent of the students surveyed thought that mathematics would be useful in the future. It would appear from these results that young people with clear perceptions of their future educational and career path are more likely to take subjects in order to meet their career expectations. Thus occupational and career preferences are seen as the determinants of the mathematics level students choose.

School Type: The schools in this study included government and private, coeducational and single-sex, and these types are strongly correlated to the mathematics level taken by students. When adjusted for the covariate *socioeconomic status* which compounds the effect that school type has on mathematics level chosen, the effects are significant at the 0.05 level ($F = 139.22$ and $p = 0.00$).

Effects of Significant Others: Contrary to popular belief, the most influential person in a student's decision to take the most rigorous mathematics units is the student him/herself. Thirty-eight percent of the students nominated themselves as the most important in their decision to take mathematics, and 19% stated that no one was influential in this decision, thus suggesting that parents and others do not have a significant influence on a student's decision to take mathematics in the upper school. This factor is most strongly related to those students who studied a university entry-level mathematics unit.

The Questionnaire (cognitive style items):

Among the most interesting aspects of the results are those related to the responses to the cognitive style orientation items in the questionnaire, despite the relatively small number (16) of such items included. An analysis of variance using three groupings of levels of school mathematics (High level - the most rigorous; Medium level, and Low level - unacceptable for tertiary entrance) indicated that there is a strong relationship between a number of cognitive style orientations among students and the level of mathematics studied. Four orientations were examined, based on the Briggs-Myers (1989, 1992) dimensions of: Extroversion - Introversion (E-I), Sensing - Intuition (I-S), Thinking - Feeling (T-F) and Judgement - Perception (J-P). Simply explained, the Extrovert - Introvert scale describes how people energise themselves; the Sensing - Intuition scale describes those things that a person pays attention to – whether they are realistic or imaginative; the Thinking - Feeling scale measures how a person makes decisions – whether objectively or subjectively, impersonal or personal, and the Judgement - Perception scale describes the lifestyle that a person adopts, be it planned or spontaneous. The data suggests that:

- Students studying high level mathematics tend to have a greater orientation towards introversion on the Extroversion-Introversion scale than students taking low level mathematics;
- The strongest relationship exists between the Sensing-Intuition scale and Mathematics Level Taken ($F = 4.05$ and $p = .007$: significant at the .05 level).

Students studying High Level mathematics have a greater orientation towards intuition on this scale than all other students. These students like to know how things work and hence are more interested in theory and theoretical approaches to teaching and learning than other students;

- Students who tend towards Judgement on the Perceiving-Judgement scale are more likely to take Low Level mathematics or No Mathematics. This indicates that the more capable students had fewer problems with such activity as planning their studies and with working to deadlines ($F = 2.48$ and $p = .05$). Low Level mathematics students have a greater orientation towards feeling on the F-T scale than all other students;
- High Level Mathematics students tend more towards perceiving on the P-J scale than all other students.

The case studies:

The case study data from the 1996 phase of the study has utilised a mixed method design drawing heavily on grounded theory. It has involved 21 case studies of upper school mathematics and non-mathematics students, and has been conducted in the three Australian states. The sample was purposive in nature, with students identified by school personnel. Students were interviewed indepth on several occasions about their feelings on the school, the background to their selection of subjects, their career aspirations and life expectations. The analyses suggest that the selection process for subjects in the upper secondary school is not only multi-dimensional, but more complex than the literature suggests. Relationships exist between students' choice or avoidance of mathematics and how they view their futures, how competent they consider themselves at mathematics, the strength of their sense of identity and the extent to which they have developed a "life-plan".

One way in which these interactions can be explored and investigated is through the concept of "identity". For example, there appears to be interrelationships amongst the students in all three states concerning the relevance they attach to schooling, whether they can imagine where they will be located (socially and physically) in the future, whether they can imagine the first step in how to achieve this image, and how they even think about the future. These factors appear to influence students' views on mathematics as a useful discipline, as well as their decision on whether or not they will study it.

Conclusion

Multi-variate analysis of the cognitive style data suggests that students who exhibit certain cognitive style orientations are likely to be drawn to study mathematics. The case study data suggests that student identity formation also may play a role in this decision. The nature of the relationship between these two factors is not yet clear, and how they interact is less clear. For example, it may be that students with certain cognitive style preferences are disposed towards particular identity formation styles. Also, it would be useful to examine more closely the extent to which cognitive style orientations are a predictor of the nature of the involvement students have with senior secondary mathematics and science. The chief investigators hope to pursue this line of research in a large scale study over the years 1998-2000.

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