Classroom Instructional Factors Affecting Mathematics Students' Strategic Learning Behaviours[1]

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The emergence of learning strategies as a critical variable in the active learning process is reflected in the promotion of a range of cognitive and metacognitive learning strategies in recent mathematics curriculum documents. This paper discusses the influence of instructional factors on senior mathematics students' development and use of learning strategies. While acknowledging that there are many causes for students' failure to use appropriate learning strategies reported findings suggest that compensatory instructional practices may limit the development and effective use of appropriate learning strategies.

Mathematics curriculum documents, both in New Zealand and Australia, promote the learner as an active constructor of knowledge. *A National Statement on Mathematics for Australian Schools* claims that "learning is best thought of as an active and productive process on the part of the learner" (Australian Education Council, 1990:16). Likewise, *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) states that "mathematics is most effectively learned through students' active participation in mathematical situations, rather than through passive acceptance and repetition of knowledge" (p. 18). Within the constructivist framework the self-regulated learner must "appropriately control his or her learning processes by selecting and reorganising relevant information and building connections from relevant existing knowledge" (Mayer, 1992:409).

The processes by which the learner selects, organises and integrates new knowledge and the behaviours and thoughts affecting the learners' motivation or affective state are referred to as learning strategies (Weinstein & Mayer, 1986). Current research suggests that students' availability, selection and use of learning strategies are critical variables in the active learning process (Anthony, in press; Wang, Haertel, & Walberg, 1993). By using various learning strategies, students can intentionally influence the form and quality of the knowledge they acquire. Recent studies in mathematics education (Anthony, 1994a) have found that the range and quality of many students' strategic learning behaviours are limited, and in many cases ineffective in assisting students' knowledge construction processes.

An individual student's strategy selection is linked to numerous factors such as prior knowledge, the nature of the task, motivation, and the availability of resources. Although interrelated, these factors can be broadly grouped into student, context and instructional factors. Student factors would include prior domain knowledge, metacognitive knowledge, learning goals and affective issues related to mood, feelings and interest. Contextual factors would include the physical learning environment, the social nature of learning (peer interactions, discussion, etc.), and the availability of resources. While not dismissing the influence of both student and contextual factors on the development and use of strategic learning behaviours (Anthony, 1996), the present discussion is limited to a consideration of the impact of instructional factors which interact in the students' learning environment. By increasing our knowledge of those factors which are most easily influenced by teacher input, we may be in a better position to encourage and develop appropriate and effective use of such learning strategies as elaboration, organisation, planning, monitoring, checking and reflection.

Method

Findings reported in this paper are from a larger study (Anthony, 1994a) which examined senior mathematics students' awareness and application of learning strategies. An ethnographic approach employed techniques of classroom observation, interviews, student diaries and questionnaires. In addition, four students participated in stimulated recall interviews, based on classroom lessons, which increased the likelihood of access to students' thoughts and covert learning behaviours (Anthony, 1994b).

Setting

Because learning strategies are not applied in a vacuum, but are influenced by a multitude of variables, the use of the authentic learning setting was seen as crucial to the research process. A year 12 mathematics class of twelve students from a large New Zealand coeducational school was the focus of the study. The students represented a cross-section of interests, motivation, achievement levels, gender and ethnicity. The class followed a pre-determined syllabus and assessment structure. Lessons typically began with homework review, followed by whole class instruction through teacher exposition and teacher-student interaction. During seatwork the teacher moved about the classroom encouraging individual students and checking whether they had any difficulties. Most students worked independently, although in two groupings there was considerable peer interaction.

Data analysis

Students' learning behaviours from all the interviews and observations were coded according to their cognitive, metacognitive, affective or resource management goal. Learning behaviours in each of these four broad classifications were then grouped into 36 representative learning strategies under a classificatory scheme. Stimulated recall data were coded according to this classification scheme to provide a quantitative comparison of strategy use.

To present a more holistic view of the students' learning processes stimulated recall interviews provided contextual descriptions of learning strategies in use. Analysis of the effectiveness of each student's strategic learning processes in specific learning episodes such as homework, discussions and seatwork, as well as an examination of factors in the students' learning environment which influenced the development and use of learning strategies, provides the basis for the following discussion.

Time at the research site (a full academic year), triangulated findings, video and audio recordings, and low inference descriptions from student reports increased the "trustworthiness" (Glesne & Peshkin, 1992) of the research interpretations.

Instructional Factors

How does instruction affect the students' use and development of strategic learning behaviours? Campione, Brown and Connell's (1989) commentary on mathematics instruction suggests an air of foreboding.

> Students are not made aware of the reasons for the skills and procedures they are taught. They are seldom given explicit teaching regarding the orchestration, management, and opportunistic and appropriate use of those skills. And they are seldom required to reflect on their own learning activities. These factors help to induce in students a flawed understanding of themselves as learners and of the academic domains they are called upon to master. (p. 111)

Instructional Orientation

Ames and Archer (1988) found that the goal orientation of classrooms, as perceived by the students, affects strategic learning. Students constantly construct interpretations of their teacher's behaviour and expectations, and the nature and purpose of classroom activity. In classrooms that emphasise task mastery goals and understanding, success is seen as dependent on effort and strategic behaviours. In classrooms that emphasise ego, ability and performance orientations, students are socialised with the goal of getting good grades, being judged able, and feel success is dependent on ability.

In a survey, adapted from *High School Science* (Nolen & Haladyna, 1990), all of the students expressed positive perceptions about cooperative work, teaching for understanding, learning from mistakes, independent thinking, and questioning. There were however, some indicators of performance orientation expressed simultaneously. The majority of students felt that they moved onto a new topic before they had really understood the old one, that you had to compete to get good grades, that it was difficult to 'keep up', and that you had to memorise lots of material. Performance orientations were also reflected in some students' negative views of public help-seeking. Avoidance of public help-seeking, related to student feelings of personal inadequacy and a wish to avoid comparison with other students, was particularly common with female students.

Karen: I honestly thought it was called a pictograph. I don't want to say anything in case it is so far wrong I embarrass myself.

Lucy: You feel a bit dumb asking questions. I sometimes ask, but if I got one wrong and the rest right I wouldn't really worry.

Brooks and Brooks (1993:7) suggest that students' unwillingness to answer teacher's questions, unless they are confident that they already know the sought after response, is a direct consequence of teachers' use of questions: "When asking students questions, most teachers seek not to enable students to think through intricate issues, but to discover whether students know the "right" answers."

Jane: Some of the time I don't understand the stuff enough in mathematics to answer questions 'cause I'll probably get it wrong. I only answer questions if I know the answers.

Emphasis on direct instruction, emphasis on skills before understanding, lack of on-line diagnosis, absence of explicit strategic instruction, assessment pressures, and the required coverage of the course may have increased the likelihood of students adopting a performance orientation. The teacher, faced with keeping the class in parallel

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Emphasis on direct instruction, emphasis on skills before understanding, lack of on-line diagnosis, absence of explicit strategic instruction, assessment pressures, and the required coverage of the course may have increased the likelihood of students adopting a performance orientation. The teacher, faced with keeping the class in parallel with other classes, sometimes looked for shortcuts, or side-stepped the more demanding parts of the course. For example, when introducing differentiation the teacher spent time on the concept of the derivative, including calculations from first principles. However, the learning goal became confused when the teacher stated, *"Now we are going to forget about how it is found and just use the formula"*.

Task Demands

The majority of the seatwork and homework time was spent on exercises which provided practice of teacher-provided examples. The focus was on computational procedures and accuracy. Students knew in advance which computational procedures were required to solve the exercises and rarely worked on problems requiring the integration of information across several topics. The teacher often reminded students that practice was the key to learning.

Mrs H: Try them all. People who have attempted lots of work tend to do better in exams.

Mrs H: The reason some of you are not doing very well is that you are not doing your homework. You need to practice until you can say, 'I have met this question before'.

While practice is important when learning procedural skills, reliance on this type of exercise limits the need for active, intentional learning. Without opportunities to do problems requiring higher-order skills, students may come to view practice as a way of memorising set examples and procedures that are to be tested in exams: the means to success is not to think through the problem and integrate information to form new ideas, but rather to recall how the teacher (or oneself) did a similar problem.

When tasks became difficult, involving high-level cognitive processing, or when the answers were not readily available, there was a tendency for students to resist task engagement or negotiate the task demands downwards.

Jake: I didn't do any homework. I don't know how to do it in class, so I couldn't do it at home.

Mrs H: Which of these (Cosine or Sine Rule) would be the easiest to prove?

Lucy: You're the teacher, you tell us.

Students mostly expected the teacher to present 'official' algorithms for solving problems step-by-step, without their needing to reflect on the process.

Mrs H: How do you think we could solve sin x = cos x?

Dean: If we haven't done it, how can we tell you?

The desire to have the information supplied, rather than to be actively involved in the generation and integration of information, was clearly demonstrated by students' preference for 'teacher-given' summaries.

Brent: Can you (teacher) write a glossary of terms we need to know?

Faye: She's a very good teacher, she writes down the answers for you.

Thus, the teacher's activities are constrained by obligations: the "students are not only 'victims' of this classroom culture but also are the 'culprits' " (Voigt, 1994:287).

In other instances, students completed tasks in ways that circumvented the intended learning demands. When tasks were high in procedural complexity (e.g., practical trigonometric investigation) most students spent more time focusing on the procedures, such as measurement, locating a suitable building and recording the information, than on the content. This was reinforced by the teacher's instructions which focused on what students needed 'to do' to complete the task, rather than the learning outcome. In other instances, to complete tasks, students copied work from others, answered questions using prompts from other students or the textbook answers, or offered provisional answers (guesswork) to indicate engagement in the task.

Another major factor affecting strategic learning behaviours is the balance between task demands, instructional support, and compensatory behaviour (Thomas & Rohwer, 1993). Supports are teacher or text provided aids that serve to prompt or sustain student engagement in the learning activity, such as information aids, opportunity for practice, or psychological support. Compensations, on the other hand, reduce or eliminate the demands, thus reducing the need for students to engage in autonomous learning activities. In this study, cognitive loads were reduced by subdividing tasks, setting short term learning goals, and providing informational products, such as a list of specific items in a test, graphs, tables, and summaries that students would otherwise need to generate. An alternative would be to provide orienting information (e.g., a list of content areas to be responsible for), a model for a process (e.g, a table to complete), or a concept map or flow diagram from which the student would form a summary.

Keywords were frequently used by both teacher and students. For example, when the teacher quickly reviewed the students' exam papers (with the emphasis on the teacher reviewing rather than the students) the following comments were included:

Mrs H: When you hear 'gradient' or 'tangent' what should you think about?

Mrs H: What are the keywords, what should the words 'rate of change' tell you?

Mrs H: Look at the paper, the most important thing is to find the keywords.

It is assumed that the recognition of keywords will help students recall the appropriate sequence of actions necessary to solve a problem. However, while a keyword may help some students complete a problem it does little to help students construct meaningful mathematical knowledge. By compensating for problem-solving demands, keywords enable students to complete a problem without necessarily understanding the problem situation, without modelling the problem mathematically, and without acquiring the intended procedural knowledge. Low achieving students, looking for ways to remember problem methods, are particularly vulnerable to misusing the keyword strategy. For example, when trying to solve the problem: *"Find the equation of the line, given m = 2 and the x intercept is 8."* Gareth first writes $8 = 2x + c$, looks puzzled, then refers to his text for a worked example. He then writes the answer as $y = 2x + 8$ using the keyword 'intercept' to identify the (incorrect) solution method!

The use of teacher supplied summaries was also intended to support the students' learning; but in reality compensated for student learning activity. On the occasions when the teacher encouraged students to participate in providing summary statements she was met with a reluctance to offer suggestions. Often negative student feedback precipitated the teacher to eventually supply all the summary material or provide an option or way out of the process: *"If you need notes on what we have done today and you don't trust your own, use Chapter 22."* With no external requirement to read for meaning, or to be selective, and with no expectation that students will be responsible for demonstrating their knowledge of the main ideas in a lesson, students have little opportunity to develop the learning strategies of selective attention, paraphrasing and organisation that are needed for autonomous, self-regulated learning.

Presentation of Worked Examples

The presentation and student interpretation of worked examples did not always promote effective strategic learning. Rarely did students ask questions related to the conceptual nature of the problem - preferring to direct their attention to the acquisition of specific information needed for the algorithmic activity. In effect, they sabotaged the instruction by selecting from it only the minimum necessary to answer the teacher's questions and achieve correct performance. The more successful students, however, did attend to the underlying structure of the worked example and used discussion as an opportunity to self-question and generate self-explanations. These self-explanations have the characteristic of adding tacit knowledge about the actions of the example solution, thus inducing greater understanding of the principles involved (Anthony, 1994c).

Opportunity to direct their own learning

To use learning strategies effectively students need time to clarify what has been happening in the lesson: "to engage in such processes as are required to evaluate the adequacy of specific knowledge, make connections, clarify, elaborate, build alternatives, and speculate" (Tobin & Imwold, 1992:21). In reality this was not the case. Teacher prompting, self-answering of questions, and limited wait time were evidenced in most lessons. Low achieving students, in particular, were often interrupted with a prompt or the answer, rather than guidance, when they hesitated or responded incorrectly.

Mrs H: What is the thing inside the square root called? Can anyone remember - it begins with v?

Dean: (calls out) Velocity.

Mrs H: Variance, not velocity. You may be asked to find the variance in the test.

If the teacher regularly answers her own questions she abrogates the need for students to engage in cognitive processing and self-management. Students learn that non-answers quickly generate teacher prompting and willingly accept a passive role in class discussion. Stimulated recall interviews did, however, reveal that students were sometimes answering questions privately; perhaps because of the expectation that others or the teacher would answer, or an unwillingness to engage in public discussion.

Adam: I noticed that she (teacher) forgot to times by n/2 but I didn't really want to speak out because I feel like, because I thought someone else might pick it up as well.

The teacher often used instructional stimuli such as questions related to comprehension and brainstorming to encourage students to make judgements about their knowledge. There was an unstated, but mainly unfulfilled, requirement that if the student judged that personal understanding was inadequate, the student would request help.

Many instructional demands were very structured. While the intent may have been to support and guide learning, students were in fact given little encouragement or opportunity to preview material, explore the text, or generally take responsibility for directing their own learning. On one occasion Adam had completed the required task and was working independently; when the teacher checked his progress she immediately set an alternative task, disregarding Adam's self-selected work.

Adam: She (teacher) said read estimation. I thought she would just come to see what I was doing. I didn't know she would tell me to read something else (surprised tone). It doesn't matter. I can do that at home sometime - it doesn't worry me. I've already done the work on estimation, but I didn't tell her, so it will be like revision anyway.

Instructional cues which allow students to anticipate learning activities also influence strategic behaviours. The teacher sometimes used a technique of going around the class for answers to a set of problems. The intention was to encourage all students to participate. However, some students reported concentrating only on thinking of an answer for 'their turn' - this practice interfered with the process of evaluating other students' answers. Likewise, the predictability of the homework review suggested to some students that there was a limited need to check work, to complete homework, or to persevere when homework became difficult.

Abe: Homework is important, but for some reason I just don't do it!...She (teacher) goes over homework most days, I can pick up things there. I tune in, have the page ready.

Lucy: I try to sort out the problem from the answer, but usually I just give up; we'll go through it in class anyway.

However, for some, the review provided an incentive to complete the homework.

Kane: It's (homework review) a good idea. I supposed it's the sort of thing like, when you're at home you think, I've got to get this done because she'll (teacher) be going over it and sort of getting into trouble type of thing.

Assessment

Performance feedback plays a crucial role in learning. Specifically, in the acquisition of procedural knowledge, attention to feedback when one has made a mistake is critical for shaping accurate metacognitive knowledge. In the present study, most students relied on the textbook answer, or the teacher, as the source for revealing correctness. Such feedback, which is simply given to the learners, without clear reference to the way they tackled the task, is unlikely to lead to effective metacognitive knowledge development. Similarly, when tests were returned the focus of both instruction and the student was on the product, rather than the learning process. Short and Weissberg-Benchell (1989) suggest that students should be explicitly taught to recognise the multiple causes responsible for learning outcomes: "Success experiences would provide information regarding task-appropriate strategies, whereas failure would provide feedback regarding task-inappropriate strategies" (p. 50).

Missing from instruction was explicit references to checking procedures and to the value of checking. Regular prompting for students to evaluate the reasonableness of their solutions, the justification of their procedures, the verbalisation of their processes, and the reflection on their thinking, behaviours that lead to opportunities to learn and develop mathematical thinking, were limited. A notable exception involved solving simultaneous equations, in which checking by back-substitution was an integral part of the procedure. Gareth expressed the view that this procedure was called the 'substitution method' because you "*substituted in at the end*"!

Formal assessment was dominated by questions requiring repetition of teacher-given procedures. Examples of questions that required a modicum of original thought either occurred at the end of the test and were awarded few marks, or were accompanied by hints so as to effectively reduce the demand for high-level thinking.

Gareth: It's more of a concern to know how to get the right answers because you don't really get checked much on understanding, all you get is a list of problems in the test.

Continuous exposure to this practice substantially reduces the task demands and the corresponding development of students' metacognitive knowledge and use of effective learning strategies (Thomas & Rohwer, 1993).

The students gained information about the structure and content of each test from teacher cues and revision of previous years' papers. The predictability of the test content and structure encouraged passive learning. Revision involved a quick flip through the class examples and teacher-provided summaries and reliance on teacher-directed study the day before the test. There was little encouragement for students to identify and evaluate their own particular learning needs.

Concluding Comments

This study highlights instructional factors which appear to contribute toward the development and use of passive learning behaviours in the senior mathematics classroom. When instruction and assessment revolve around the end product of the task, students are encouraged to view learning in terms of 'doing' or 'completing' a task and gear their strategies to that end. Bereiter (1990) labels this adaptation to classroom routines, in which students focus on activities as work, on completion and production rates, as the 'school-work module'. Learning is marginalised and becomes no more than coincidental with school-work.

There were occasions when the teacher, in trying to support the student's learning, effectively reduced the learning demands on the student by doing the student's thinking and processing for them. Such practices included the supply of summaries, the use of keywords, teacher prompting and limited wait-time when questioning, and encouragement of elaborations which focused on recall of procedures rather than concepts. As students persuaded the teacher to be more direct, and to lower the ambiguity and risk in classroom tasks, instruction inadvertently mediated against the development and use of appropriate and effective learning strategies.

Additionally, the assessment structure encouraged the use of learning strategies appropriate for rote memorisation and recall of previously seen examples, providing little incentives for students to use metacognitive monitoring and control strategies. Students' knowledge, or hopes, that the teacher would direct their revision a day or so before each test limited the need to plan or schedule revision. If one believes that learning requires independent thinking assessment should include new tasks requiring new applications of general principles or procedures.

While most students wanted to learn with understanding, and valued cooperation and the sharing of ideas, in reality, they lacked the knowledge and control of a range of appropriate learning strategies. Instruction must not only focus on the need for understanding and learning from errors, but must also model a wide range of learning strategies and provide students with feedback on their use of strategies. Furthermore, instruction that engenders appropriate beliefs about mathematics and learning is needed to ensure that students' strategy selection will be directed at meaningful knowledge construction rather than task completion. Until classroom learning environments encourage students to perceive what they are doing as the construction of knowledge many students will fail to construct appropriate metacognitive knowledge, and will continue to use inappropriate and ineffective learning strategies.

NOTE: This is a shortened version of the paper that won Dr Anthony the 1996 'Practical Implications Award' sponsored by Curtin University.

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