THE ROLE OF LEARNING STRATEGIES IN MATHEMATICS: A CASE STUDY OF FAILURE TO LEARN.

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ABSTRACT: *Observations of Gareth's learning behaviours reveal a student who is keen to succeed, is on task, and completes homework. However, despite being actively engaged in* ***doing*** *mathematics, Gareth makes little progress in* ***learning*** *mathematics. As part of research examining senior students' use of learning strategies, data relating to Gareth's learning behaviour was collected from questionnaires, interviews, observations and stimulated recall interviews. This paper proposes that some students', and in particular Gareth's, learning difficulties are compounded by inadequate use and control of appropriate learning strategies. Gareth's cognitive learning strategies are directed towards to the goal of collecting given information about the 'way' to do a problem, recording the method and hopefully recalling this method on a similar example in the test. Gareth's metacognitive behaviour lacks appropriate monitoring and checking strategies. Social-support strategies, such as help seeking and modification of a task, are used inappropriately, often inhibiting learning rather than enhancing learning.*

Research from a constructivist perspective has shown that learners' goal, beliefs and prior knowledge affect learning but 'a crucial aspect missing from this current discussion on constructivism is the strategies used by students in constructing their own meaning' (Wong & Herrington, 1992). However increasingly, research on learning strategies has shown that what a student learns depends to a large degree on how he or she has learned it. Research in domains such as reading and languages have found that successful students are those who possess a range of cognitive strategies that enable them to select, acquire, organise and integrate new knowledge and metacognitive strategies that enable them to regulate and monitor learning.

Consider the mathematics student Gareth, who is hard working, keen, answers questions, takes notes, is on task, does homework, makes use of textbook resources, and studies for tests. What grade does Gareth achieve for his efforts? - an 'E'! Too often we are quick to blame failure on lack of student ability, inadequate prior knowledge or poor motivation. This paper proposes that an examination of the strategic learning behaviours may in part explain some students' persistent failure to learn.

Data to support this discussion is from a larger research study examining 6th form (year 11) mathematics students' use and awareness of learning strategies in the classroom and home environment. Gareth was one of four target students, who participated in stimulated recall interviews to obtain detailed self-reports of learning strategies used during actual lessons. Two lessons were recorded using two video cameras: one camera was focused on the teacher and the other on Gareth, creating a split-screen image of teacher and student on a single tape. Gareth viewed segments of the lesson and was requested to discuss, as fully as possible, his learning behaviours. Triangulation of data from observation of 51 lessons throughout the year, interviews, questionnaires on learning strategies, test preparation and homework activities, plus reference to Gareth's workbook provided a profile of learning strategy use.

Gareth's strategy use is varied and includes cognitive strategies such as rehearsal, linking to prior knowledge, highlighting, note-taking, and coding; metacognitive strategies of monitoring, attending to specific features of the problems, checking, answering questions, anticipating lesson direction, planning and revision; and social-support strategies of help seeking, monitoring the teacher, setting the environment and resourcing information. How do we reconcile Gareth's wide repertoire of strategic learning behaviours with his persistent failure?

LEARNING EPISODES

As strategy use and consequent learning outcomes are determine by the individual student, the task demand and the context of learning (Garner, 1990) a discussion of Gareth's strategy use is linked directly to specific episodes of learning which typically occurred in the class and home environment: review of homework; introduction of new content; seatwork; homework; and revision for tests.

Review of homework or seatwork: Gareth found homework review sessions a useful opportunity to correct work and find out how to do those problems which he had been unable to do at home. If homework had not been marked he spent a lot of time putting ticks or crosses on work in class. For example, when reviewing homework on standard deviation Gareth ticked every data entry. He is keen to answer teacher questions, but needed to refer to his own work to get the answer on many occasions. If he has a problem incorrect Gareth always copies the teacher's example into his book. Additionally Gareth likes to actually do any calculations rather than just copy the teacher's answer. For example when Gareth is copying down a standard deviation problem he calculated the mean (9.2 + 1.2 +... 4.6) ÷ 10 rather than attending to the teacher's explanation on checking procedures. These metacognitive strategies of selectively attending to arithmetic procedures and monitoring understanding based on whether or not he can perform the calculations are both ineffective and inefficient in learning the desired content of the review session.

Introduction of new content via explanation and worked examples: Gareth exhibits similar learning strategies during teacher exposition of new content. He copies all the information from the board, but attends to each step separately rather than the links between each step. Because of his focus on one step calculations he is often able to answer teacher questions such as "What will the mean be?" or "Factoring will give you?" He also responds to cued questions. For example, when studying calculus, questions such as "What do we do first?" always elicited the response "*Differentiate*" - a fairly safe answer! About 30 percent of his answers are incorrect and Gareth reported that guessing answers was an appropriate strategy. He reasons that if you are wrong the teacher will give you the correct answer, and it is good to answer lots of questions as it will go on your report at the end of the year - "*Gareth participates in class discussion or stuff like that.*" Thus Gareth employs the strategy of answering questions to gain teacher approval and information, rather than to assist in monitoring understanding and elaboration.

As well as answering questions Gareth also evaluates other student's answers. But when evaluating correctness Gareth's criteria is often based on knowledge of the person answering, teacher response, or matching of the answer with his own, rather than any critical examination of the content of the answer. For example, Gareth reported "*I was thinking yes he's right, his answer is the same as mine and if two people get the same answer it must be right.*" The fact that the teacher went on to negate the answer did not register with Gareth. This practice of evaluating answers by match is constantly reinforced by students checking problem answers with textbook answers, or comments from the teacher such as "*Did anyone else get 7.5 - fine, it will be right.*"

Seatwork: Gareth always works on task during this period, being one of the first in the class to begin work and one of the last to finish at the end of the lesson. He uses examples on the board to guide him through the first problems. This strategy is reinforced by the fact that seatwork problems are strongly related to what the teacher has just done.

When examples are not on the board Gareth will, where possible, complete seatwork problems with reference to worked examples in the text. Sometimes he will copy the worked example prior to starting a section of exercises. He includes the explanation statements as supplied by the text and sometimes puts these explanations alongside his own working *"to help remember what to do"* but reports no elaborative statements or self-explanations for the procedural steps during this process. In contrast, research concerning the use of worked examples (Anthony, 1991) has shown that good students make frequent self-explanations of the procedural steps thus aiding elaborative encoding of the new material.

To complete problems he copies step by step procedures used in the worked examples. This strategy can lead to incomplete or incorrect solutions. For example, when completing the exercise: 'Find the turning point of the function $y = x^2 - 6x + 11$, and the values for which the function is increasing or decreasing', Gareth copies the steps: 'differentiate and solve for 0', to find the turning point (3,2), but continues by following the given steps: 'substitute x = -2 and substitute x = 0'. Gareth interpreted these two text explanations as generalised rather than specialised procedures and applied them literally to his problem. Gareth's misuse of the supplied text explanations reinforces the idiosyncratic constructivist nature of learning. For a good students who can generate his or her own explanations, the given explanations would be redundant, however for the poor student who has little understanding, such explanation may actually confuse rather than clarify and perhaps limit learning (Anthony, 1991). Gareth's reliance on these explanations supports Blais' (1988) position that providing students with a maximum of explanation will often serve to perpetuate the 'remedial processing' of novices.

Gareth reported *"I like doing problems in class because in class you can get the teacher to help you if you have problems. You learn maths when you work one to one with the teacher."* When he asks for help he expects the teacher to show him how to do the problem: *"It's easy with a teacher there because if you've got problems you can go an see her and she'll tell you the answers and go over the questions."* This is usually the case; the teacher either writes all or most of the solution out for him. Clearly, getting the teacher to do the problem, or copying step by step from examples are effective strategies for achieving Gareth's goal of task completion but offer little chance of any real knowledge being constructed. At best Gareth's learning strategy will result in acquisition of an algorithmic procedure which will not readily be transferable to related applications.

Homework: Gareth attempts homework; except when deadlines from other subjects create time pressures He sees homework as a time to consolidate what you did in class: *"The more practice you get the more understanding you'll have."* When homework is assigned during the lesson he previews the exercises and makes some judgement as to the amount and difficulty. At home, after tidying his study area and arranging his books, he looks over all the exercises. He does not read any of the text explanation or worked examples but goes straight to the exercises and *"if I've got any problem I first go straight to the back of the book and see their answer and work backwards to the question. If I haven't got any problems I just sort of whiz through them ... I just whiz through the first line of each section."* Gareth's evaluation is based on metacognitive experiences of whether the material is 'easy or hard'. An 'easy' problem is one which can be completed, with no concern as to the reasonableness of the answer. Furthermore, Gareth's selective marking of only the hard problems *"because I've looked them up to help with working backward but if they are straightforward I won't always mark them."* means that opportunities to learn from errors are limited.

Revision for a maths test: Unlike most other students in the class, Gareth plans revision, both in terms of time and topics. Most other students reported attending to teacher cues, whereas Gareth appeared relatively unaware of cues indicating which material would be in the test. Gareth does several hours of revision in a quiet room, trying some problems, reading notes over and over again, reading over worked examples in the book and doing a few problems from last year's revision book. He explains that last year when he practiced examples the night before *"my brain just couldn't handle all the examples, and I kept bumming out, so now I don't go over the examples the night before because it doesn't really help me much, I just lose concentration."* This is an example of how one's metacognitive knowledge, determined by past learning experiences, affects strategy selection. When asked how Gareth thought he could improve his performance he replied *"Go through the examples slower."* Gareth also makes reference to memory strategies such as rehearsal: " *If I have to memorise the formula that they wont give me or a graph, I just write it out a few hundred times."*

THE ROLE OF STRATEGIES

When learning new information students need to activate and utilise their prior knowledge so as to integrate it with new information in a coherent and logical manner (Weinstein & Mayer, 1986). Lack of prior domain knowledge severely limits Gareth's ability to use elaboration strategies such as linking, paraphrasing, imagery or self-explanation. Often Gareth tries to compensate for lack of knowledge by locating the text reference as soon as the teacher introduces a new topic. This may enable him to answer teacher's questions based on what he reads in front of him, and Gareth possibly deludes himself into thinking that he understands the topic.

Numerous studies have found that metacognitive behaviour has proved a vital component of expert mathematical performance and learning. Important metacognitive strategies are monitoring the learning process (Anthony, 1991, Siemon, 1992), planning for learning and reflection or evaluation of the learning process (Hiebert, 1992; Wheatley, 1992). The ability to correctly monitor understanding has a direct bearing on students' subsequent cognitive actions (Peterson, Swing, Stark & Waas, 1984). If students do not notice that they are not understanding they are unlikely to engage in remedial strategic process (Anthony, 1991). Gareth's references to understanding such as: *"I was understanding why she put the numbers in over there"* and *"I understand why she put the 'f' row (sic) there"* commonly refer to arithmetic or organisational features of an example. These criteria are influenced by Gareth's belief (metacognitive knowledge) that doing a mathematics problem correctly or having a record of a how to do a problem is what learning mathematics is all about: *"As I work through it I might learn how to do it once and keep going with the same ideas sort of thing."*

To evaluate his learning Gareth relied on task completion, checking with text answers or teacher verification. Strategies to cope with incorrect work by trying to work backwards from the answer or look for a similar problem, although commonly used by all students, were liable to misuse in Gareth's case. For examples, when doing exercises on standard deviation problems Gareth explained that he got them all wrong because he hadn't drawn the lines of the table when the question said "draw a table".- again we see the influence of the importance of doing the correct steps and attention to peripheral aspects of the task.

CONCLUSIONS

Regardless of Gareth's will and effort input, the combination of ineffective learning strategies and weak domain knowledge precludes successful learning. Much of Gareth's learning is of a 'passive' (Mitchell, 1992) nature, dependent on the teacher or text to tell him what to do and how to do it. To a large extent his cognitive strategies involve duplicative processing (Thomas, 1988), involving unaltered encoding or mental recycling of the given information. Furthermore, his monitoring and help seeking strategies are directed to task completion rather than understanding. There was little evidence that Gareth could evaluate the effectiveness of his learning strategies and consequent learning process or devise alternative ways of thinking and improving his performance.

The implications for mathematics instruction are twofold. Firstly teachers need to be more aware of the role of learning strategies and in particular the use learning strategies by pupils who are persistently failing. Research (Mitchell, 1992) has found that most teachers are unaware of, or underestimate the extent of the presence of passive learning tendencies in their classroom. Secondly, findings (Anthony, 1993; Garner, 1990) that much of students' failure to use appropriate strategies maybe directly attributable to classroom instructional factors suggest we need to continue to address the challenge to provide instruction that directly teaches knowledge construction strategies. Such instruction would value reflection of the learning process, self monitoring of understanding, and the setting of goals by providing feedback on the use of learning strategies and demonstrating improved performance. Recent research (Cardelle-Elawar, 1992) demonstrating that performance can be improved by instruction aimed at increasing students' awareness and control of learning strategies, does offer some hope for student like Gareth.

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