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DEVELOPMENT OF METACOGNITIVE SKILLS IN SCIENCE STUDENTS

Dr. Sushma Jakhar
Principal
Indus College of Education, Rohtak

ABSTRACT

One of the enduring problems that educators in the sciences must face in designing units is how to ensure a well-structured knowledge base without overburdening students with facts, formulae and inert knowledge. Science teachers at university must recognise that units of studyshould be designed not only for broad coverage of the field but also for the opportunities to master important concepts and practice key intellectual abilities. Of fundamental importance is the development of students' problem solving skills and metacognitive abilities in the first yearof study, as this creates the foundation for future learning. It is proposed that metacognitive skills can be fostered by developing learners' awareness of the problem solving approaches of experts, by offering modeling and training in problem solving strategies and by employing pedagogies that enable learners to monitor and self-correct their own problem solving approaches.

INTRODUCTION

In this paper we discuss a project that is directed towards the effective development of metacognitive skills of first year science students. We do this in the light of current findings on the lack of well-developed metacognitive skills in learners and also by drawing on our own experience of teaching in a regional university catering to both internal and external students.

The changing profile of students currently entering universities in Australia is creating pressure for change in teaching approaches. Current student intakes include students from diverse backgrounds with a significant proportion arriving with little or no background in science. This requires university teachers to support learning in what is for many first year students a new area of learning. A recent Australian study indicates that failure rates in science courses range from 5-21% with a mean of 11% and that around 30% of first year science students seriously consider withdrawing from study in their first year (McInnis, & James 1995). These facts alone indicate that as science educators must think beyond merely designingcourse content and curricula to address the serious problem of student attrition rates.

Diversity in learning backgrounds also characterizes the student body. Many external students have been away from study for a number of years and may have the learning skills required for tertiary study. Moreover they may feel a sense of isolation in not being able to work co-operatively and see the quality of their own work in relation to others enrolled in their units. It clearly is important to generate positive feelings of success in study by integrating appropriate learning skills in the teaching of science. Separate study skills programs can lead to short term improvement in some learning strategies, but are less successful in the longer term. "Students do not always apply strategies they have learnt to other contexts, because they are unaware that they are relevant to the task. It may be that even when they recognize that a particular strategy is relevant, they do not know how to apply it." (Chalmers & Fuller 1996). In our experience many students do not see the relevance of general study skills programs as they cannot apply them directly to what is being taught, and their first priority is to complete the next assignment.

The special needs of first year students are recognized in the literature and a number of approaches have been suggested to involve students in active learning (McInnis, 1995,1998). For example, Zadnik, de La Harpe and Radloff (1998) proposed that students become involved in producing a student conference in order to achieve a focus on written and oral communication skills. Mishra (1998) proposes students prepare discussion papers and engage in collaborative learning, while Zeegers, Martin & Martin (1998) document the success of process-orientation instruction and student directed tutorials for first year Chemistry students. What these studies have in common is the movement away from teacher driven paradigms of learning, a greater emphasis on understanding how students approach their own learning and the use of student directed, small group techniques to foster higher level cognitive goals.

METHODOLOGY

Let us consider briefly how first year science subjects are taught in many universities. Over emphasis on rote learnt content and terminology still characterizes much science teaching at tertiary level, to the detriment of student learning. First year biology students typically have to cope with as many new terms as students learning a new language, apart from trying to understand the new concepts being introduced. If lecturers still hold to a transmission approach in their teaching combined with a focus on content coverage, this forces students into surface learning approaches.

Another characteristic of university science subjects is that scientific concepts may be largely removed from the everyday life of students and real world applications. Students in chemistry must struggle with unfamiliar names and symbols, while they also need to understand new concepts, which are often presented in a decontextualized, abstract manner. Often the pace of delivery is such that there is little opportunity for students to understand new concepts in a qualitative way first, to explore them and to verbalize their ideas, before applying theseconcepts to fewer familiar situations. However, teaching in science need not be about content coverage, factual recall and the application of formulas, but about problem solving.

There is a vast literature on problem solving in the sciences, which is a largely untapped resource (Gabel, 1994). There is also a growing emphasis on developing higher order cognitiveskills of university science students (Barouch, 1997, Sleet, Hager, Logan & Hooper, 1997, Bucat & Shand, 1996). Essentially what matters most in learning in the sciences is the capacity to solve problems, to analyze and classify data, to gather evidence about solutions and to apply and test theories. Clearly, the knowledge base in science is expanding too fast to ensure that students cover all aspects of scientific knowledge within the duration of a university course. The alternative is to offer students learning experiences that allow for conceptual exploration and acquire the thinking skills needed for their future learning. It is on this assumption that we seek to develop a coherent framework for development of metacognitive skills.

The term metacognition refers to a learner's knowledge about his or her processes of cognition and the ability to control and monitor those processes as a function of the feedback the learner receives via outcomes of learning (Metcalfe & Shimamura, 1994). Thus, two essential components comprise metacognition: knowledge and control. Metacognitive knowledge refers to what a learner understands and believes about a subject matter or a task, and the judgments s/he makes in allocating cognitive resources as a result of that knowledge (Flavell, 1987, Brown, 1987).

CONSTRUCTIVIST PROCESSES

The issue of self-regulation in learning centers directly on the assumption that learners interact with new subject matter in constructivist ways. In effect, knowledge is constructed by the learner because the learner is in control of the knowledge acquisition process. That is, learners search for meaning and understanding in unfamiliar knowledge domains by attempting to regulate whatever strategies they possess in the context of whatever relevant knowledge they believe they have. Unfortunately, for many learners in first year, both the knowledge base and the skills necessary to regulate the processes are poorly developed or have never been taught (Jonassen and Reeves, 1996).

Learners need to be given opportunities to develop understanding of concepts and learning process skills, and be given ample opportunity to practice them in the context of the subject matter domains where they will have to use them. Research on cognition shows that students who think about their learning are better learners than those who do not (Weinstein and Meyer, 1991). The most fundamental tenet of constructivism is that students cannot learn from teachers, they can learner only by thinking about what they are going to do or what they believe, or thinking about the thinking they have just engaged in. In fact there is evidence that students who do nothing more than reflect on their learning on a regular basis with a good listener, do better than students who do not (Heath, 1964).

DESIGN OF INTERVENTION PROGRAM TO METACOGNITIVE AWARENESS

Based on extant research on metacognitive training, we propose a scheme for the development of metacognitive skills for science students that involves six phases (See Figure 1). The environment for metacognitive training will combine Web-based scenarios with problem simulations in order to engage learners in actual problem solving and reflection on their own problem solving strategies.

In Phase 1 the concept of metacognition is operationalised. For the problem in question, the students need to become aware of the problem solving processes involved. For example, with respect to the Aqua Ear Problem, this requires analysis of the question, how to plan a solution, What strategies might be applicable as opposed to trial and error, what self-monitoring skills could be used.

Phase 2 involves the design of the problem environment. For particular problems in a topic in Physics or Chemistry for example, examine the different ways in which an expert and a novice student might answer the problem.

The problem is then presented to the student to work on in Phase 3. Student responses are monitored in Phase 4 to decide if any Intervention (Phase 5) is required.

Phase 5 presents' students with a scenario or problem where they are assisted in the processes and procedures of problem solving, and made aware of their own problem solving strategies.

In Phase 6, successful students are presented with further problems in the topic area to check whether they have transferred the strategies learnt during Phases 3 and 4. If they have not, training continues.

In Phase 7 students are given the opportunity to reflect on their problem solving.

The final Phase 8 involves a refinement of the training to create design guidelines for a problem solving environment in different subject areas (biology, physics and chemistry) in order to foster metacognition.

CONCLUSION

The project described here is the initial phase of a two year research project dedicated to development of metacognitive skills in science. We believe that students' metacognitive skills can be developed significantly by taking a proactive approach and by designing an environment specifically for problem solving and metacognition. Teachers who are expert in one or more of the respective domains come to the teaching/learning transaction with well- rehearsed knowledge about their own skills and procedures in the domain. For a teacher, this metacognitive knowledge has developed over years, for example, by way of studying diagrams and flow charts in text, making observation of experiments in lab, and noting conditions and situations in an everyday environment that reveals relationships and realities of pertinent phenomena. Indeed, most teachers begin to derive significantly more metacognitive knowledgewhen they actually teach. That is, the process of teaching forces them to think of the material interms of the way the information will be learned. New learners, on the other hand, come to the subject matter domain naive with respect to this knowledge.

This project proposes that metacognition can be developed in contexts that engage students in self-monitoring their own problem solving approaches, in scenarios where they can ultimately use that knowledge. This requires creating real life anchors for development of problem solving skills and enabling students to explore, test and review their own strategies. Though the project is still in the initial phases, we anticipate that the research will result in significant changes to the way teaching in the sciences are currently conceptualized.

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