[O14] Open ended problem solving and the influence of cognitive factors on student success

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Abstract

Most problem solving activities in chemistry focus on the development of quantitative skills and the solving of algorithmic problems. Problems which are more open ended in nature are less often encountered and are more difficult to develop and to assess in terms of student performance. However, such problems present advantages in terms of motivating students and in providing a more realistic experience of problem solving as a skill.

We have developed a set of context-based open ended problems which are being used with chemistry undergraduates at several levels. The problems have been evaluated for intellectual demand and compared to traditional chemistry based problems of similar demand level. Students' success in tackling these problems is being investigated. The influence of cognitive variables such as working memory and field dependence is being investigated and attitude testing and interviews are being used to probe the effect of this style of problem on undergraduate engagement and motivation.

Introduction

A survey published recently by The English Manpower Services Commission showed that 80% of the top 10% of British companies invested significant amounts of time and money into training (Buzan, 2003). Employers from around the world have identified the main areas requiring improvement as: Oral communication skills, written communication skills, creative thinking, planning, problem analysis, problem solving, motivation, analytical thinking, acquiring further knowledge and good interpersonal skills. Many of these skills, however, are often absent, and students need to have acquired these skills and be able to tackle unfamiliar and/or open-ended problems (Belt *et al*, 2005). The ability to apply their knowledge to the situations that their future employers will present them with is essential.

Problem Solving

'Whenever there is a gap between where you are now and where you want to be and you don't know how to find a way to cross that gap, you have a problem' (Hayes, 1991). Problem solving is something encountered in all aspects of life (Reid and Yang 2002). It is a skill that makes a large part of a graduate's employment and students should be better prepared with problem solving skills when they reach the workplace. Developing problem solving skills has been the subject of much research into science education (AAAS, 1993, NRC, 2003, Barak and Dori, 2005 and Zoller, 1999). The types of problems set in examinations or assessments in higher education chemistry are largely algorithmic (Kempa and Nichols 1983). Algorithmic problems use mainly lower order cognitive skills (LOCS) whereas more open ended problems call upon higher order cognitive skills (HOCS). Setting more challenging problems will enable the development of HOCS, and

allow students to overcome those challenges and solve more open ended problems. This approach will help a student's progression through the stages of intellectual development.

The use of context to teach sciences has been the subject of much research. Obviously solving chemistry problems requires a good knowledge of chemistry (Frazer, 1982). However, problem solving in many cases has been unsuccessful even when students possessed most of the requisite knowledge (Sumfelth, 1988, Shaibu, 1992, Aidigwe, 1993 and Lee *et al*, 1996). Students with basic knowledge of chemical terms did not recognize the relationships between concepts and therefore were unable to apply their knowledge (Sumfelth, 1988). Problem-Based Learning aims to stimulate students to learn by presenting them with a real life problem that they wish to solve (Margetson, 1998). Rather than just giving them the content and saying, 'learn this', questions are asked before all the information is given. Using previously acquired knowledge, acquiring new knowledge and learning new skills, they are expected to, answer the question, solve the problem.

Cognitive styles

Much research has been undertaken into the factors that affect problem solving (Norman and Yang, 2002). Gabel and Bunce (1994) proposed that the factors affecting students' success in problem solving are threefold: the type of problem and the underlying concepts of the problem; the learner characteristics, including cognitive styles, developmental levels and knowledge base; and learning environment factors, including problem solving strategies or methods, individual or group activity.

Working Memory Space (WMS)

The WMS is where new information from the outside world and information retrieved from long term memory (LTM) is held and processed. The size of the WMS coupled with previously held knowledge in LTM is therefore a major determining factor in learning and problem solving (Johnstone and EL-Banna, 1986 and Johnstone, 1997). In group work the individual working memory spaces of the members of the group is combined. This can minimise the effect of limited WMS (Reid and Yang, 2002). Many studies have concluded that co-operative problem solving has lead to greater success (Johnson and Johnson, 1975, Tingle and Good, 1990, Basili and Sandford, 1991, Kempa and Ayob, 1995 and Qin *et al*, 1995). Such group work can also help overcome misconceptions by sharing information, exchanging experiences and ideas (Basili and Sandford, 1991). Tingle and Good (1990) studied 178 high school students in chemistry and provided further evidence that students were able to teach each other by using models and analogies and asking questions during group discussion. Success in problem solving may increase as a result of this.

M-Capacity

M-Capacity is analogous to working memory and is defined as the mental-attentional energy available for a particular task (Pascual-Leone *et al*, 1978). It has also been termed M-power, the power of a person's mental concentration mechanism (Niaz, 1988). M-capacity can be broken down into structural M-capacity (M_s), the total available M-capacity and functional M-capacity (M_f), the amount of M-capacity that is actually used. For those with high processing capability M_f is said to be close to M_s and those with low processing capability M_f is much lower than M_s. As with the information processing model (Johnstone and EL-Banna, 1986 and Johnstone, 1997) the M-capacity of a person is a determining factor in problem solving.

Field Dependence/Field Independence

Field Dependence/Independence is also a determining factor in academic achievement. A student who is field dependent has difficulty separating relevant information from irrelevant information or 'signal from noise' (Tsaparlis, 2005). A field dependent student will be processing both signal and noise and will therefore be using more functional M-capacity (M_f) than a field independent student who will process only signal (Niaz, 1989).

Attitude and motivation

'If university teachers are asked, what is the most important student characteristic associated with successful studies, they usually mention traits such as attitude, motivation, and genuine interest.' (Berg, 2005). Through pre and post course attitude questionnaires Berg found that several students displayed significant changes in attitude towards learning chemistry, both positive and negative (Berg, 2005). The most significant changes were further investigated through interviews with the students.

Methodology

This paper describes the investigation of the effect of cognitive styles and attitude on the problem solving abilities of students in a department of chemistry. A set of context-based open-ended problems was designed with the aim of helping students develop higher order cognitive skills. Tests for cognitive styles were performed by groups of students and were followed at a later date by problem solving sessions. Attitudes towards chemistry, problem solving and the use of real-life context were also assessed by the use of questionnaires, before and after the problem solving sessions. The problems were evaluated for difficulty and then ranked by the students after the problem solving sessions. Problems were tackled individually and in groups. Groups were arranged according to field dependency scores. Data was then gathered from the test results, performance in the problem solving sessions, performance in A-Levels and the degree so far. Statistical analysis was then performed on these data to look for correlations between any of the variables. Attitude questionnaires were then analysed for significant changes. From this a small number of students were selected for interviews.

Below is an example of one of the problems.

> *The rivers and oceans contain levels of dissolved gold of between 5 and 50 ppt. Extraction of gold from seawater has been seriously considered many times. Approximately how many kg of gold are present in the world oceans?*

Results and Discussion

Early results show a few general indications: There appears to be a correlation between A level scores and problem solving ability. Attitudes towards problems with real life or work related context have increased positively. All of the students found the more open ended problems more challenging yet more enjoyable than conventional ones. From the sessions with the 30 05/06 Year 3 students, where all the problems were tackled individually, there is an indication of correlation between M capacity and attainment, i.e. problem solving ability. From 60 06/07 Year 2 students' sessions, where problems were tackled in groups and individually, there appears to be a correlation between Field Independence and problem solving ability.

The interviews with year 2 students proved encouraging with plenty of positive comments about the problems. E.g. '*fun, got to discuss and decide which route to take to solve problem', 'explore range of answers and knowledge of chemistry', 'better to have questions in context!', 'everyone threw in own ideas and discussed', 'had to use brain in a better way', 'enjoyed whole experience, exercised mind'.*

More statistically significant data will emerge with repeated sessions with each year of the chemistry degree course and this year's second year students will be followed throughout their course enabling a longitudinal study to assess improvements in problem solving ability with practice. Further interviews and case studies will take place and analysis of exam scripts to assess performance on algorithmic problems will enable comparisons to be made with the new problems. The impact of industrial experience will also be investigated in problem solving sessions with year 4 students some of whom have had a year out working in industry and others who have not. New problems with a more work-based/industrial context have been prepared for these sessions.

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