NEW PERSPECTIVES IN SCIENCE EDUCATION
PIXEL

Insights into Science Students' Problem-Solving Strategies in the Chemistry Laboratory

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Abstract

Problem solving in the chemistry teaching laboratory is the essence of good science education practice and is increasingly being recognised and valued as an approach to science teaching from primary to higher education. This paper gives an overview of a research study which identified the problem solving processes Year 1 undergraduate science students used while undertaking problem-based learning tasks in the chemistry laboratory. The study conducted used a qualitative research methodology of observation, followed by in-depth semi-structured interview. The literature is rich with studies that attempt to describe differences between the problem-solving behaviours of experts and novices across a wide range of discipline and subject areas. Generally, importance is placed on domain specific knowledge for the expert, which is developed through experience. This is of particular relevance to this study since the students have a range of different prior experiences in the 'chemistry' and 'experimental/practical' domains. Suggestions regarding the nature of the different strategies identified are offered as topics for discussion in relation to well established problem-solving strategies in other curriculum areas. Furthermore, this paper offers an insight into how the problem-solving strategies of these students may be related to theories on how students approach learning. Possible implications and recommendations for laboratory teaching staff are made. This is particularly relevant in the context of easing the transition from secondary to higher education.

1. Introduction

1.1 Problem-solving strategies

The literature is rich with studies that attempt to describe differences between the problem-solving behaviours of experts and novices across a wide range of areas [1]. Generally, importance is placed on domain specific knowledge for the expert, which is developed through experience. This is of particular relevance to this study since the students have different prior experiences in the 'chemistry' domain.

One study, by Benner [2] put forward a novice to expert scale for solving problems. This was drawn from research in clinical nursing practice, strongly linked with the Dreyfus and Dreyfus (1980) model [4]. In this Benner recognised the difference between 'know that' and 'know how', with the latter being achieved through experience and that experience is a pre-requisite for expertise. She describes experience as 'the refinement of preconceived notions and theory through encounters with many actual practice situations that add nuances or shades of differences to theory'. However, both the Dreyfus and Benner models have been criticised because of their apparent absence of social structure or social knowledge [5]. This criticism is of particular interest due to social nature of the learning environment in which this study is situated.

Elio and Scharf [3] describe the difference between novice and expert problem-solvers in physics. They describe an expert as not only knowing more than a novice, but also by the difference in how they organise their knowledge about a domain and use that knowledge during problem-solving. This is summarised as novice problem-solvers relying on equations, where as experts rely on principles and concepts. Since some of the students who haven't studied chemistry, will have studied physics (or may have studied neither/both), this model was considered important when analysing the approaches to problem-solving of the students in this study.

In relation to science education, many studies have been carried out into problem solving and Cartrette and Bodner [1] summarise the outcomes of these:

'Based on these reports, we have learned that: problem solving success and conceptual understanding are not always coupled; memory structure and organization are constructed in a more sophisticated manner among those problem solvers with more experience in a domain; that our efforts to explicitly teach problem solving strategies do not always meet success; and that problem solving is often accomplished by heavy reliance on algorithms or weak heuristics (p. 643)'.

1.2 Students approaches to learning

Research investigating how students approach various tasks resulted in the identification of three distinct approaches to learning: Deep, Surface and Strategic [6-7]. An important outcome of this research revealed that, though students may have a preferred approach to learning, they will adapt their approach depending on the demands of the teaching, learning and assessment environment. A problem-solving approach such as the one described in this paper aims to encourage a deep approach [8].

What this paper offers is an insight into how the problem-solving strategies of our students may be related to theories on how students approach learning, using the deep, strategic, surface model. To this end the following questions are addressed:

- How do students solve problems in the laboratory?
- How do these strategies relate to students' approaches to learning?

2. Methodology

This study adopted a phenomenographic approach. Phenomenography, as a theoretical framework, seeks to study the different ways people experience a particular phenomenon [9]. The sample chosen represents a broad spectrum of students taking an introductory chemistry laboratory module as part of a general 1st year science programme. The students were following various BSc programmes. The aims of this module were to develop practical skills and to demonstrate a range of chemical concepts. The number of students taking the Year 1 chemistry laboratory module is typically around 180, with approximately 60 students working in the lab at one time. For the problem-solving task, the students worked in groups of six; four of these groups were observed. The groups were constructed to contain students with a range of experience in chemistry.

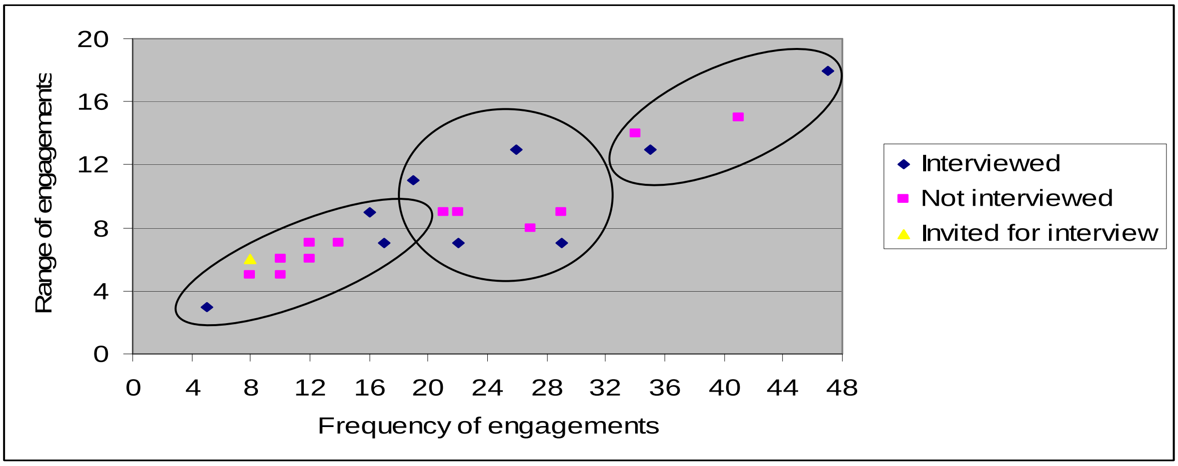
This module generally follows an expository or 'traditional' approach to laboratory work, with students' working in pairs or on their own. However, within the module a number of context-based problems are set for the students which they have to solve in groups. It was on one of these occasions that the research took place. Students were given a problem statement a week before the lab session was scheduled. Students then worked in groups, prior to the designated lab class, to develop an approach for solving the problem. Students were also expected to carry out independent research. The students worked through the problem in the lab and prepared their presentation after the lab session. Students then delivered their assessed presentation the following week.

An observation schedule and field notes were used to record the activities of the students in the laboratory. Instances of 'engagement' were noted, as well as the frequency of questions asked and answers given per student. The quality of questions asked or answers given was not measured. The type of 'engagements' covered six categories:

- organisation
- problem content
- practical/skills
- presentation/assessment
- calculations/maths
- interaction

Each of these contained a number of sub categories which were coded to allow for quick and accurate recording of the observations. From this, the total number of observations and the number of subcategories of observations for each student were determined (see figure 1). This allowed us to identify the breadth and depth of engagement for each student and select students for interview, choosing students across the full range, including those students' with the lowest and highest number of engagements.

Figure 1: Graph showing the range of engagements against the frequency of engagements



The usual data collection tool in phenomenography is an 'open, deep interview' [9]. A similar approach was followed here. The transcripts were analysed using NVivo. Content analysis was used by coding the interview data and identifying experiences relating to deep, strategic and surface approaches.

3. Findings and discussion

Overall, the study showed that students relied heavily on the internet for information, which was not surprising. The study supported adoption of group work as students recognised the benefits from this and the associated social aspects of learning. Assessment has long been seen as driver for learning and this was also the case in the study.

3.1 How do students solve problems in the laboratory?

Two clear strategies emerged from the interview data. Of the four groups observed, three adopted a very similar 'novice' like strategy, whilst the other adopted a more 'expert' like strategy. With regard to the 'novice' like strategy, students reported a number of common themes. These included:

- Organising their knowledge according to apparent/obvious features of the given problem
- Reliance on weak heuristics
- Use of provided material

These findings are similar to those reported by Elio and Scharf in relation to physics problems, who noted that novices tended to suggest solutions and equations soon after reading the problem statement, whereas experts first engage in a kind of qualitative analysis – generating additional useful information about the problem situation that was not explicitly stated in the problem statement [3]. Furthermore, they noted that novices organised their knowledge about problems according to surface features of their problem statements (e.g. pulley, incline-plane), while experts organise knowledge based on deeper features of the problem statement.

In relation to the group that reported expert-like characteristics, throughout the process they kept relating results back to the original problem and worked constructively as a group discussing results and bouncing ideas off each other. These findings support the criticisms raised by Peña regarding the absence of social structure or social knowledge in other problem-solving models as it is seen here to be integral to 'expert' problem-solving [5].

The results suggest that their abilities in problem solving are not related to whether or not they have studied chemistry before since the majority adopted a similar approach despite their varied backgrounds in chemistry. This is contrary to other research which suggests that organisation is constructed in a more sophisticated manner among those problem solvers with more experience in a domain. This led to questioning what other factors might give rise to different problem solving abilities [1].

3.2 How do these strategies relate to students' approaches to learning?

The interview transcripts were analysed in relation to the surface, strategic and deep approaches. Students who take a deep approach have the intention of understanding, engaging with, operating in and valuing the subject [10]. Characteristics of such students include:

- Actively seek to understand the material / the subject
- Take a broad view and relate ideas to one another
- Relate new ideas to previous knowledge
- Tend to read and study beyond the course requirements

Motivation for students who take a surface approach tends to be that of jumping through the necessary hoops in order to acquire the mark, or the grade, or the qualification [10]. Characteristics of such students include:

- Take a narrow view and concentrate on detail
- Fail to distinguish principles from examples
- Tend to stick closely to the course requirements
- Are motivated by fear of failure

The strategic approach is that which students are said to take when they wish to achieve positive outcomes in terms of obtaining a pass or better in the subject [10]. Students taking this approach:

- Intend to obtain high grades
- Organise their time and distribute their effort to greatest effect
- Ensure that the conditions and materials for studying are appropriate
- Are alert to cues about marking schemes

Table 1: The key characteristics from the interviews with relate to the three approaches

Surface	Strategic	Deep
Doing minimal research	Asking tutor for help with calculations	Group discussion
'Plugging' in figures to a formula	Very task focused	Trying to get an idea of what was going on
Doing enough to get by	Sharing the work equally in terms of practical work	Bouncing ideas off each other
Approach guided by time	Working in mixed ability pairs in terms of their previous chemistry experience	Aware of the bigger picture
Low interest	Getting results right in the end	Relating their work back to the original problem

4. Conclusion

These initial results suggest that across the individual's interviews there was a typical spread of approaches evident. Furthermore, there were higher instances of characteristics which related to surface and strategic approaches. One implication of this study is that we need to be more aware of the learning approaches of our students, as well as their subject knowledge, as they enter into higher education. This should enable the students to take full advantage of more student-centred approaches, such as problem-based learning which demands problem-solving ability among other skills, such as working effectively in groups. This is particularly relevant in the context of easing the transition from secondary to higher education in the sciences [11]. Therefore, teaching staff need to carefully scaffold such learning opportunities.

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