AN INVESTIGATION OF THE EFFECTS OF A NOVEL TEACHING APPROACH ON STUDENTS' LEARNING OF CHEMICAL IDEAS

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Abstract: The aim of this paper is to provide a preliminary insight into the use of a novel method of discovery instruction at degree level chemistry. The fundamental principle in instruction strategy was to provide minimal guidance to students with the intention of improving their autonomy. To do so, students only received feedback to their questions through online discussion board and they were not provided with any more guidance during the module. The approach used replaced traditional lectures with an intervention consisting of an individual learning package, including an interactive booklet, an online discussion board and a range of other activities designed to increase the level of student autonomy. The topic focus was a first year module on polymer chemistry. The sample involved the whole first year cohort, consisted of 176 undergraduate students. In order to evaluate the students' level of conceptual understanding, a diagnostic test was developed and administered to the whole sample prior to and after the intervention. Further information on student's views of the teaching approach was collected using a mixture of open-ended questionnaires, and one-to-one or group interviews, involving sub-sample of 24 students after they have completed the module. Preliminary findings suggest that the minimal guidance in teaching chemistry at tertiary level is not an effective instruction approach in terms of improving students' conceptual understanding of key concepts. However, the majority of students argue that they have improved a variety of skills with the help of the teaching approach.

Keywords: higher education, chemistry education, minimally guided instruction, conceptual understanding, and skill development

INTRODUCTION

This research study focuses on a novel teaching approach designed to teach polymer chemistry at university level. Educators apply new teaching approaches as they believe, in their personal teaching philosophy, that the new teaching approach applied is likely to be more effective than the other teaching approaches. Unfortunately, many educational approaches which are being used by teachers are not evidence-based approaches, as distinct from many medical or engineering approaches. In particular, approaches which involve technology, IT or any kind of novelty in teaching and learning tend to be regarded as good approaches before subjected to rigorous evaluation.

Moreover, although scientists pay attention to solid data and sound theories in their scientific work, it could be argued that they seem to pay less attention to empirical and theoretical approaches related to their teaching practices. This points to the need for rigorous research into the impact of novel approaches in teaching and learning in order to improve the teaching experience of students at tertiary level education.

The most common recent practice in education domain for investigation of teaching approaches is to create experimental research designs in order to compare them with more traditional instruction strategies. However, the comparison of instructional strategies which have been created in different theoretical frameworks is an extremely complex process for various reasons and conclusions drawn from those studies can be quite deceptive. Hence, each suggestion should be addressed and assessed in its own context with its own aims and outcomes which can lead to more productive results than searching for an ultimate superiority of one method over another. This research study is set to investigate principles of specific instruction method in its own context with its own expected learning outcomes.

LITERATURE REVIEW

The teaching approach investigated in the study reported here has number of aims, of which the most central is to improve students' autonomy and their subject specific skills. The capability of being able to manage one's own learning was always seen as an essential aim of education. Carl Rogers (1969) described the educated man as the man who has "learned how to learn" himself.

In a similar vein, Paris (1998) has claimed that being the decision-maker in terms of nature and the pace of learning is a fundamental requirement of motivation in science, as well as collaboration and challenge. However, science faculties have been blamed for lecturers having a tendency to teach in a way that they themselves have been taught, and resisting any change (Alters & Nelson, 2002).

Wallace (1996) concluded that increased student autonomy and letting students have control over their learning can lead to a rise in students' engagement. An enhanced role for personal autonomy is also desired by students (Osborne & Collins, 2000). Possibly, the most common practice in improving students' autonomy in education is discovery instruction strategies. The discovery-based approach can be defined as an instruction strategy in which unassisted learners are required to construct or discover their own solutions to problems or ways to accomplish a task, and support is usually provided when educators have independent evidence that the learners cannot perform the task or achieve the goal unaided.

The effects of variations in discovery instruction on learning have been reviewed in a combination of laboratory and field-based studies by Mayer (2004) by Kirschner, Sweller and Clark, (2006) and by Sweller, Kirschner and Clark, (2007). In his comprehensive review, Mayer (2004) discussed research reviews on the discovery of problem-solving rules culminating in the 1960s, the discovery of conservation strategies culminating in the 1970s, and the discovery of LOGO programming strategies culminating in the 1980s, and concluded that guidance-based instruction methods are more effective than discovery-based instruction methods in helping students to learn and to transfer. He also stated that within discovery-based strategies, guided discovery methods are more effective instruction strategies than unguided discovery methods. Kirschner, Sweller and Clark (2006; 2007) similarly defended the idea that although unguided or minimally-guided discovery instruction approaches are very popular and intuitively appealing, evidence from empirical studies over the past half-century consistently indicates that discovery instruction is less effective and less efficient than instructional approaches which place a strong emphasis on guidance of the student learning process. They also claimed that discovery learning approaches basically ignore the research studies on the structures that constitute human cognitive architecture. All three of these reviews presented empirical evidence from prior research studies that had investigated the effects of variations in guidance on learning and concluded the superiority of direct instructional strategies over discovery-based instruction strategies (Gagne & Brown, 1961;

Kittel, 1957; Shulman & Keisler, 1966; Brainerd, & Brainerd, 1972; Dalbey & Linn, 1985; Fay & Mayer, 1994, Moreno, 2004; Tuovinen & Sweller, 1999).

As discussed above, there have been many research studies which have attempted to compare discovery-oriented instruction approaches such as inquiry-based teaching, problem-based teaching or discovery teaching with more direct instruction approaches such as traditional lecturing, transmission teaching and cognitive task analysis instruction in experimental research settings. However, after comparing the test results of discovery instruction methods with those of direct instruction strategies, researchers usually reach the conclusion that one group of students performed better in those particular implementations. Drawing from this conclusion, they tend to generalize their findings to the relative superiority of one instruction strategy over the other. Usually, however, these research designs do not generate enough evidence for researchers to make generalizable claims about causes. In such cases, there are too many different variables in play to make valid inferences about which factors are responsible for the differences. As a result, a great deal of evidence presented in support of both discovery-based instruction approaches and direct instruction approaches, is subject to critique. Hence, in this current research study, the instruction strategy employed was not set to be compared with other instruction strategies in experimental research designs. The instruction strategy employed here is investigated in its own context with its own aims and objectives in order to reveal its merits and drawbacks.

METHODOLOGY

First, for the investigation of students' understanding of key concepts in polymer chemistry, pre- post-test questionnaires were employed. To assess levels of students' understanding of key ideas about polymer chemistry, the diagnostic questions were devised by the researcher in collaboration with professionals in the domain. 176 first year undergraduate chemistry students completed the same questionnaire before and after completing the intervention module.

First, in order to monitor general differences in students' responses, a paired-sample t-test was used. The students' responses were first coded according to the coding chart prepared and then enumerated in order to be transferred to the SPSS programme. With the help of the programme, differences between their pre-intervention and post-intervention responses were compared using a paired-sample t-test at the 0.05 level of significance. If the p value is smaller than 0.05, there is a very strong likelihood that an external influence has caused the result, as it is very unlikely that the result was produced by chance alone. The main external influence in this research study that might cause such results was expected to be the instruction strategy of the macromolecules module, although it would not be realistic to claim that the results were produced by the macromolecules module itself alone.

The second test that was applied to report the results was a chi-square calculation, and this was also calculated at the 0.05 significance level. After the completion of the module, if meaningful learning has occurred, the expected change will be in favour of the answers including fewer or no signs of misunderstanding compared with the pre-intervention results. Students who responded in the first survey by revealing a misunderstanding of an idea may have learned something during the macromolecules module which leads them to respond differently to the second questionnaire.

The second focus of the research study required analysing students' view of their chemistry modules in the course as a whole. Two types of data were gathered. First of all, to collect data about the students' preferences for different chemistry modules and the ways that they have been taught, a descriptive questionnaire was developed. 176 first year undergraduate chemistry students completed the questionnaire after the intervention. Following the descriptive questionnaire, and to add depth to the data, interviews were held with students. As expected, three groups of student views emerged after the analysis of the descriptive questionnaire, namely, students who found the teaching approach enjoyable and helpful in terms of developing their knowledge and understanding of chemistry (74 students, 42%), students who found the teaching approach either enjoyable or helpful in terms of developing their knowledge and understanding of chemistry (88 students, 50%), and students who found the teaching approach neither enjoyable nor helpful in terms of developing their knowledge and understanding of chemistry (14 students, 8%). Interviews were held in order to probe students' view of the teaching approach and the chemistry teaching at tertiary level in general. 24 first year undergraduate chemistry students were selected from three groups, six personal interviews with two representatives of each group and six focus group interviews were undertaken with mixed groups of three students.

FINDINGS

In order to analyse the pre- and post- intervention results of the diagnostic questions, paired samples t-test ($p < .05$) was employed. Analysis shows that the students' responses to the diagnostic questions, which aim to measure changes in students' understanding of key concepts in polymers, were not significantly different before and after the intervention of the instruction strategy. This suggests that students' understanding of key concepts in polymer chemistry has not been significantly developed during the macromolecules module. Another important result from the questionnaires was that, for the majority of questions, the number of answers with a sign of misunderstanding of concepts has not changed significantly at post-intervention when compared with pre-intervention. Moreover, in one particular question, the number of answers with a sign of misunderstanding of concepts has increased significantly.

A further interesting finding from the questionnaires was that, it seemed some common misconceptions in children's ideas remained with students through to their tertiary-level education. For instance, the misconception of "burning always decreases the mass of a material" was written by some students in their explanations. That could easily be used as a supportive argument for the robust structure of misconceptions.

In terms of students' views of the module, many students particularly enjoyed the independent learning approach, and some students thought it had particularly helped them to develop their understanding of chemistry concepts. An interesting point to consider in the results of the descriptive questionnaire was that modules that were particularly enjoyed differed from the modules that students considered the most helpful in developing their understanding of chemical concepts. This may be explained by many students having preferences for particular lecturers, rather than particular teaching approaches.

Although during the interviews the majority of students (19 out of 24), claimed that they have improved their independent learning skills, almost none of them was able to exemplify a change in his/her studying habits.

CONCLUSIONS AND DISCUSSION

The results of this study suggest that guidance in discovery instruction strategies is not a luxury but a necessity for developing conceptual understanding of future chemists. Minimally guided discovery instruction strategies do not contribute to students' knowledge and understanding of ideas, moreover they might actually lead to an increase in students' misunderstandings. Although the students in this study were only from one chemistry department in the UK, the findings of the present study might provide some clues about the quality of students' learning in similar chemistry instruction strategies.

The results of this research study also suggest that minimal guidance in discovery instruction approaches does not seem to work for the improvement of self-assessment and the ability to transfer knowledge to different contexts. It is not an effective approach to treat students' misunderstandings, as in some cases it may lead to worse results.

Students seem to appreciate creativity and novelty in their modules. Interview results explicitly show that even the unfavourable opinion holder students reported that they had enjoyed changing their studying routine. However, students' self-assessment of their improvement appears to be hugely different from the results of the pre-test, post-test comparison.

It was discussed in the literature review that a great deal of evidence presented in support of both discovery-based instruction approaches and direct instruction approaches, is subject to critique because they assess instruction strategies in experimental design studies. In this research study we have examined the impact of a discovery instruction strategy in its own context and its findings show similar results with the recent literature reviews on the topic (Mayer, 2004; Kirschner, Sweller and Clark, 2006).

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