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Problem solving and other
higher-order cognitive skills (HOCS)

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HOW STUDENTS PERCEIVE GROUP PROBLEM SOLVING: THE CASE OF A NON-SPECIALIST CHEMISTRY CLASS

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ABSTRACT: In this work, the authors present students' impressions of a series of open-ended group problem solving exercises that were used with students during an undergraduate chemistry course at King Fahd University of Petroleum and Minerals (KFUPM). This was the students' first experience of this approach to problem solving activities. The preliminary results are very promising and call for changes in the way chemistry is taught at KFUPM. [*Chem. Educ. Res. Pract.*: 2003, *4*, 387-395]

KEY WORDS: *case study*; *group work; problem solving; open-ended group problem solving; students' perceptions*

INTRODUCTION

Academic programs in Saudi universities are generally modeled on systems encountered in the United States. Thus, courses are modular and the academic session is divided into semesters. Within this framework, the teaching of chemistry at university level in Saudi Arabia is fairly traditional, i.e. lectures, practical classes, and small group seminars/problem sessions, and methods are essentially teacher/teaching centered as opposed to student/learning centered. In various areas of Saudi society over recent decades, there has been a drive to modernize and develop, and the higher education system is obviously important in carrying this process forward.

One of the more effective methods that have recently emerged in teaching is Problem-Based Learning (PBL). PBL is a curriculum development and instructional approach. PBL is not only cooperative, but also teaches students skills like creativity, open-ended problem solving, motivation, seeing the problem in context, higher-order thinking, authenticity, learning how to learn and disciplinary knowledge bases, and transferable skills such as communication and group work. PBL involves placing students in the active role of problem-solvers confronted with ill-structured problems which mirror real-world problems (Johnstone, 1993; Johnstone, 1993; Allen, Duch, & Groh, 1996; Savin-Baden, 2000).

PBL has as its organizing center the ill-structured problem which

- is messy and complex in nature;
- requires inquiry, information-gathering, and reflection;
- is changing and tentative;
- has no simple, fixed, formulaic, "right" solution.

The use of problem solving case studies present an approach building on the principles of PBL but which can be used within focussed areas of the curriculum rather than adopting a whole curriculum approach. Case studies may provide extended problems that are related to applications or real contexts with incomplete or excessive data, require independent learning, evaluation of data and information and do not lead to a single 'correct' answer. Case studies have a long history in many subject areas and their value within chemistry has long been recognized (Garratt & Mattinson, 1987; Pontin, Ario *et al*, 1993; Wenzel, 1995; Werner, 2001; Overton, 2001). A case study should:

- involve the learning of chemistry by requiring students to learn independently;
- be active in style;
- involve a work-related context;
- involve the development of transferable skills.

Although case studies require students to apply new knowledge in order to solve the problem, they are perhaps often more structured than the traditional PBL approach, where a problem may be presented as a single statement or short paragraph.

In this study, we present students' impressions of a PBL-type approach, using a case study as one of the activities, that was conducted during an undergraduate chemistry course at King Fahd University of Petroleum and Minerals (KFUPM). This was not an example of PBL in the true sense, as the activities related to only a small part of the curriculum and it was the only instance of this type of learning that the students would experience. Nevertheless, some of the key features of PBL activities where present, such as complex problems, independent learning and the absence of a single correct answer. The activity was introduced as a trial into an essentially very traditional course. The preliminary results are very promising and, hopefully, will encourage other educationalists in Saudi Arabia to use similar student-centered methods, initially at the university level and eventually at the high school level.

METHODOLOGY

Before the start of the activity, the following topics were discussed with the students: roles within teams, how to build a successful team, and meetings skills. The students were divided into small groups of 5-6 students. The students had to hold meetings at a regular time, some of which were attended by the instructor to observe group performance. A final group presentation (20 min. long) of the results had to be delivered as a PowerPoint presentation, poster, or any other form chosen by the students. The final grades of students depended on the following factors: the quality of the group's work, peer evaluation, and a final group presentation. The grade awarded for the quality of the group's work and the group's presentation were the same for everyone in the group, so peer evaluation of each group member's contribution was used to provide individual grades for the students.

Before starting the activity, the reproduced on next page questionnaire was given to the students.

The group activities were used with engineering students who are taking a chemistry class called "Basics of Environmental Chemistry". According to the best knowledge of the investigators, the group problem solving method has never been applied in science courses in Saudi Arabia before.

Initially, the students were given a simplified activity (See activity A below) in order to familiarize them with group-based learning and also with open-ended problem solving. The first part of the activity is important for those who will work in environmental-related

Educational Survey

Please answer to your best on a scale from 1 to 5 according to the following:

1	*2*	*3*	*4*	*5*
Strongly agree	*Agree*	*Undecided*	*Disagree*	*Strongly disagree*

1) Freshmen Chemistry is difficult.

1	*2*	*3*	*4*	*5*

2) I prefer teachers to use new ways of teaching

1	*2*	*3*	*4*	*5*

3) Chemistry is a boring subject

1	*2*	*3*	*4*	*5*

4) I do not like chemistry, because I do not have personal opinion about things I learn

1	*2*	*3*	*4*	*5*

5) Studying with other students in a group enhances my understanding

1	*2*	*3*	*4*	*5*

6) Studying with other students in a group will improve my grade point average (GPA)

1	*2*	*3*	*4*	*5*

7) I have adequate verbal communication skills

1	*2*	*3*	*4*	*5*

8) I have reasonable skills for solving open-ended problems

1	*2*	*3*	*4*	*5*

9) I have adequate teamwork skills

1	*2*	*3*	*4*	*5*

10) The University should introduce a "verbal communication skills" course.

1	*2*	*3*	*4*	*5*

11) The University should introduce a "group assignment" course.

1	*2*	*3*	*4*	*5*

12) I prefer instructors to include group activities in their courses, but there is no need for a separate course.

1	*2*	*3*	*4*	*5*

13) Future Employers will appreciate greatly those taking a group exercise during their undergraduate course.

1	*2*	*3*	*4*	*5*

work. However, the students had not encountered any of the topics before. The second and third parts of the activity were taken from literature (Garratt, Overton, & Threlfall, 1999). The problems had been designed to develop critical thinking skills and required logical thought and judgement to be used.

Initially, the students received this exercise well but this was quickly transformed into a clear awkwardness. This feeling resulted from the issues the students faced, such as how the group members could find a suitable time for all of them to meet outside the class time. But, eventually, the students were able to find their way through, and completed the assignment.

Activity A

1. Identify the purpose of the following techniques:

Gas Chromatography (GC)
High Performance Liquid Chromatography (HPLC)
Atomic Absorption Spectroscopy (AAS)
Inductively Coupled Plasma Spectroscopy (ICP)

2. One way of reducing the levels of CO, NO_x and hydrocarbons in the exhaust gases from car engines is to fit catalytic converters. The most effective catalyst is made of platinum, and this complexes with lead which therefore poisons the catalyst. Lead-free petrol was therefore developed in order to make the use of catalysts possible.

Which one of the following sentences best expresses the flaw in this argument?

A It is possible to remove lead from platinum.
B Lead is present in engine oil, and so this will poison the catalyst.
C Nowadays the best catalysts contain rhodium as well as platinum.
D Lead-free petrol was developed because of the potential health hazard of lead emissions from the exhaust.

3. Construct a logical argument from the following statements. (Establish the logical sequence).

A The Haber process used to manufacture ammonia from nitrogen and hydrogen is carried out at a temperature between 400 and 500°C.

B The reaction

$$3H_2 + N_2 \rightleftharpoons 2NH_3$$

is exothermic, so Le Chatelier's principle indicates that ammonia production would be favored by low temperature.

C At room temperature, the rate of reaction between nitrogen and hydrogen is too slow to be commercially useful.

After the students had completed activity A, they were given a more advanced group problem solving activity. The exercise is called "Tales of the River Bank" (Belt, Evans, McCreedy, Overton, & Summerfield, 2002; Belt, Overton, & Summerfield, 2002) and was used after some slight modifications to make it more appropriate to the background of the students. The activity is a case study set within the context of an investigation of environmental problems along a river system. Students assume the role of an investigation

team following a complaint about a reduction in the number and size of fish caught along the river. By considering both temporal and spatial factors, the students identify an array of possible causes. The students must consider the impact of land use along the river and identify possible sources and types of pollution. They are provided with a limited amount of analytical data and must decide what further samples to collect and what analysis needs to be carried out. As further data and information is made available, the groups are required to consider environmental issues, pollution, sampling, analytical techniques, water quality, data analysis / interpretation, toxicity, and remediation. The activity was run over 4 sessions and the students had to spend at least 10 hours in associated work outside of the classroom. The students initially had difficulty starting the problem as they were not given detailed instructions by the tutor but they soon began to tackle the issues and successfully completed the activity and 'solved' the problem.

After the completion of the activity, the students were given the same questionnaire once more. The time between the first and second questionnaire was 2 months.

STUDENTS' PERCEPTIONS

When the group problem solving exercises were introduced, the students were not immediately comfortable with them since they were not used to taking full responsibility for acquiring knowledge by themselves. Although they may find lectures from teachers tedious, students prefer not to take the responsibility themselves for acquiring skills. However, as we proceeded through the educational experiment, it was obvious that the students became more enthusiastic about the exercise.

In order to gather the impressions of the students (n = 17), we conducted the questionnaire twice as mentioned previously and the results are summarized in Table 1. The responses of the students are expressed as numbers of responses.

One of the most important observations regarding the two surveys is related to the reduced choices of neutral response from first round to the second round. Obviously, this is related to the students having had more first hand experience of many of the issues raised in the survey.

Furthermore, students' responses towards the experiment were generally very positive, as can be seen from the Table and from the analyses below. However, the authors recognize that these positive responses, especially after the second survey, may be affected by other factors such as instructor-students relations that developed during the activities, motivation by the instructor and the motivational aspects of teaching by context. These factors were part of the whole experience for these students and are very important for any successful educational process. The nature of these types of activities makes motivating students and using a real life context much easier than more traditional teaching methods.

It is interesting to analyze each response individually. In order to gauge the students' perceptions of chemistry, they were asked whether they felt that chemistry is a difficult subject or not. In the first round of the survey, only 2 students felt that chemistry is an easy subject. However, after the second round of the survey, 10 out of the 17 students answered that chemistry is easy. To be objective, we cannot say that the positive change is purely due to the exercise. Other factors such as active teaching and learning methods could also affect students' response. If the learning activity had been a very easy one, this would also have explained this shift in response. However, this is not the case. The 'Tales of the Riverbank' is not a trivial exercise and can be quite demanding for specialist chemistry students. Also, the positive change occurred among those who were undecided, but the number of those believing chemistry is difficult remained the same.

TABLE 1. *Summary of student responses to questionnaire before and after PBL activities.**

	Statement		SA	A	N	D	SD
1	Freshmen Chemistry is difficult	initial	4	6	5	2	0
		final	1	6	0	9	1
2	I prefer teachers to use new ways of teaching.	initial	4	6	6	1	0
		final	8	7	2	0	0
3	Chemistry is a boring subject.	initial	3	6	6	1	1
		final	0	6	0	7	4
4	I do not like chemistry, because I do not have personal opinion about things I learn.	initial	4	5	7	1	0
		final	1	2	1	10	3
5	Studying with other students in a group enhances my understanding.	initial	1	3	10	2	1
		final	7	9	0	1	0
6	Studying with other students in a group will improve my Grade Point Average (GPA).	initial	0	2	8	5	2
		final	2	6	3	5	1
7	I have adequate verbal communication skills.	initial	1	8	4	3	1
		final	0	3	2	12	0
8	I have reasonable skills for solving open-ended problems.	initial	1	2	7	6	1
		final	0	12	1	4	0
9	I have adequate teamworking skills	initial	1	4	10	1	1
		final	1	11	1	3	1
10	The University should introduce a “verbal communication skills” course.	initial	3	6	5	2	1
		final	12	4	0	1	0
11	The University should introduce a “group assignment” course.	initial	2	3	8	2	2
		final	7	6	0	4	0
12	I prefer instructors to include group activities in their courses, but there is no need for a separate course.	initial	6	3	6	1	1
		final	11	6	0	0	0
13	Future employers will appreciate greatly those taking a group exercise during their undergraduate course.	initial	2	4	8	2	1
		final	8	8	1	0	0

* S.A. = Strongly agree, A. = Agree, N. = Neutral, D. = Disagree, S.D. = strongly disagree.

Regarding the use of new teaching methods by teachers, 10 students felt that this should be the case. After the exercise, a further positive outlook was realized; 15 students felt that this practice should be implemented. Of course, once these new methods are embedded within a course the students will no longer see them as novel and this very positive response may then be reserved for other ‘new’ approaches.

Only 2 students responded that chemistry is not a boring subject, however after the exercise, 11 students felt that chemistry is not a boring subject, which is a dramatic change. Again, other factors could have contributed to these changes as mentioned before but the use

of active learning, group work and a real life context must surely have been contributing factors in this response.

There is a perception that in science education any answer that a student gives will be right or wrong and that there is little chance for students to hold opinions (Kooser, 1982; Emundson, 1993; Johnstone, 1993). This is one of the reasons that drove many educational scientists to introduce open-ended problem solving into the sciences. If we look at activity A, for instance, we find that there is more than one plausible answer or at least there is more than one way to respond to the questions. Before conducting the exercise, 9 students said that they do not like chemistry, because they cannot have a personal opinion about things they learn (as opposed to other subjects such as history, sociology, psychology and management.) However, after the exercise 13 students disagreed with the expression "I do not like chemistry, because I do not have personal opinion about things I learn". The full credit must go to the new approach

The initial opinion of students towards group learning was not very positive. Only 4 students were accepting the approach. After the experience, a dramatic change was observed, 16 out of the 17 students felt that group learning enhanced their understanding. Once again, this might not be purely due to the new activity as they were briefed on the advantages of teamwork before beginning the activities.

When it comes to the effect of group learning on improved GPA's (grade point average), the story is quite different. The students did not feel a positive correlation between the improved GPA and group learning even after the exercise. This can be easily explained if one analyzes the applied grading system at KFUPM. KFUPM follows the traditional American system. Grading in this system is relative; i.e., the performance of some of the students will affect others' grades either positively or negatively. Although a certain student may feel that group learning will enhance understanding, such type of learning might affect him negatively by awarding a lower grade. This is a clear call for the grading system at KFUPM to be revisited.

When the students were asked whether they have adequate verbal communication skills, 9 students answered positively. However, after the exercise, an interesting outcome was observed. Twelve students said that they do not have adequate verbal communication skills. It seems that students initially had an inflated impression of their own skills. Once that they were required to use those skills in order to communicate effectively, there self assessment may have become more realistic.

Initially, the majority of students did not feel that they had reasonable skills for solving open-ended problems. After the exercise, however, 12 students said they have those skills. Before the exercise the students may never have had to solve open-ended problems before. The approach used here presented them with an open-ended, ill defined problem for which they had insufficient data and they were able to achieve a successful outcome, so demonstrating their problem solving skills.

When the students were initially asked if they had adequate teamwork skills, 12 students did not respond positively. In the second survey, 12 students said they have those skills. This shows that teamwork skills can be developed and demonstrated to students by motivation and training. The authors believe that the number of positive responses could increase further if these sorts of activities were applied on a larger scale in the KFUPM system.

Then, students' position towards the introduction of a new course "verbal communication skills" was sought. Before the exercise, 8 students did not support the idea. However, the response changed dramatically after the activity; 16 students supported the idea. As mentioned previously, it seems that the students realized the importance of verbal communication skills based on their communication difficulties during the activity.

Compared to the previous issue the students have a relatively lower ambition for a new course that is completely devoted to group learning. Thirteen students supported the idea following the activity, which is much higher than their initial response (5 students). However, when they were asked about the point: "I prefer that instructors include group activities in their courses, but there is no need for a separate course.", their support was amazing. Sixteen students then liked the idea. This definitely gives a clear message to the instructors that cooperative learning (CL) methods should be increasingly practiced even if the whole course in not geared towards CL.

Finally when students' initial opinions were sought about the following point "Future employers will appreciate greatly those taking a group exercise during their undergraduate course.", only 6 students agreed with the idea. In the second survey, however, the number jumped to 16 students. By all standards, this is a great achievement for the exercise.

TUTOR OBSERVATIONS

The following are recommendations for tutors wishing to experiment with the use of group working or open-ended problem solving. These are based on the experience of running the activities described here by a tutor who was a novice in this way of teaching before the investigation began.

A very important aspect of an efficient educational process is motivation. Teachers should be able to show students why they have to know something, or why they should learn it, and what the impact of learning a certain thing or doing certain activity is on their life. So, new exercises should not be performed without motivating the students before and during the process.

Instructors should select the group members. They should not leave it to students. Good students like to work with each other and weak ones will end up working together. Also, friends prefer to work with each other. The ideal number for this sort of activity is 4-6.

Unless problems are severe, students should be left alone to sort out their problems.

CONCLUSIONS

The experience of both staff and students during this limited trial of a new approach to environmental chemistry has been a very positive one. Although student sample is small in statistical terms, the feedback was so positive that it must encourage the further development of this approach to teaching chemistry. There is the possibility that the students responded so positively to the experience because it was new to them and the instructor may have conveyed enthusiasm for the new approach. Nevertheless, the study presents strong arguments in favor of the further implementation of context-based problem solving, group work and collaborative learning into traditional course provision.

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