MAKING THE MOST OF PBL: IMPROVING STUDENT LEARNING IN PRINCIPLES OF INSTRUMENTAL ANALYSIS (PIA)

Wang Jianjun June
Chew Swee Cheng
Teong Ping Nam

Temasek Polytechnic, Singapore 529757

In the last academic year, the subject team for Principles of Instrumental Analysis (PIA), urged by their need as educators to improve student learning, took on the arduous task of planning, implementing and evaluating an instructional programme using the PBL approach. The result of which was a marked improvement in the results of the students. The effectiveness of the programme was not only reflected in a very positive attitude of the students towards learning but also in their evaluation of the facilitators and the programme as a whole. This paper describes the details of a follow-up study of the effectiveness of the programme with a new cohort of students. As these students have gone through one semester of PBL with the Organic Chemistry team in the previous year, the author would like to see if they have adjusted further to the learning approach with the new subject Principles of Instrumental Analysis. Results from periodic evaluation exercises conducted with the students reveal a favourable trend of better adjustment of the learners both towards the team dynamics, the problem-solving process and self-directed learning.

INTRODUCTION

Much has been reported in current research and literature on the benefits of adopting the PBL approach in the classroom. Banerjee and De Graaff (1996) talked about students becoming actively involved in their learning by analysing problems and finding solutions to them by applying previous knowledge acquired and picking up new ones. This sort of deep learning leads to better retention of knowledge and easier retrieval as the knowledge has become part of the learners' working knowledge.

The subject team for Principles of Instrumental Analysis (PIA) consists of two tutors, one relatively new and from the industry and the other has teaching experiences. Both had had experience with PBL the previous semester. Both tutors had been consistently rated by students and colleagues as having the attributes described by Grasha (1994) as being particularly advantageous when implementing a student-centred methodology such as PBL. In his classifications, the "expert/facilitative/personal blend" of teaching style or what he calls cluster 3 works well for "small group discussion", "self-discovery activities", or "PBL" etc. He also commented that such a blend works well for students who are willing "to take initiative and accept responsibility". The teaching team felt that the year 1999 cohort of Chemical Engineering students exhibit the level of maturity needed for such a full-scale PBL implementation.

THE STUDY

Profile of Students

The subject PIA is an application subject, which requires students to have a good knowledge base of both Principles of Inorganic & Physical Chemistry (PIPC) and Organic Chemistry (OC); both foundation subjects taken in year 1 semester 1.

A comparison of the results of the experimental group (year 1999) and those of the control group (year 1998) reveals that the experimental group is a lot weaker with the percentages of A & B consistently lower in both subjects than those of the control group. The average mark is also much lower. The details are shown in Table 1.

Table 1
Chemistry background for both groups

Subject	**PIPC**		**OC**	
Two groups	**Control group**	**Experimental group**	**Control group**	**Experimental group**
% of A & B	40.9	21.6	34.8	18.4
% of C	32.6	32.8	36.4	27.2
% of D	22.0	39.2	18.2	35.2
% of F	4.6	6.4	10.6	19.2
Average mark	66.3	61.9	64.9	58.5
Std. deviation	9.0	12.1	11.1	13.1

The control group experienced 6 weeks of PBL in PIA with the rest of the course conducted in the traditional mode while the experimental group had a 15-week course in PIA conducted in full PBL mode.

Exposure to PBL Methodology

Both groups had some exposure to PBL methodology prior to this study and the details are shown in Table 2.

Table 2
Students' PBL experience for both groups

	Control group	**Experimental group**
Experience	Prior from OSH	Prior from OC 2
Level	Brief	Quite extensive
Characteristic	Information-based	Technical-based

The experimental group had some advantages in areas such as teamwork. Students in this group knew their team members and their work styles very well as they had already worked together for half a year. Most of the teams can work effectively.

The subject team members were motivated to introduce PBL into PIA by the reasons cited in Hannah & English (1999), namely, their desire to equip the students with better life skills to cope in the working environment and to encourage them to be more responsible for their learning.

Description of Overall Plan

Two problem statements were used to drive students' learning of the subject throughout the whole semester. The main objective of the problem statements was to enable students to apply the theories learnt from both self-directed learning and facilitation to real problems. Students were required to engage in self-directed learning, collaborative learning, and problem solving during the facilitated sessions and peer tutoring sessions. During the facilitated discussions, students analyse the problem statement and record facts from previous experiences and new issues to be investigated. The tutor closely monitored this process to give students a sense of reassurance and security. Students took an active role in generating learning issues, deciding how they would study, and evaluating what they have learned. This process is helpful in the development of students' self-directed, lifelong learning skills (Barrows & Tamblyn, 1980; Walton & Matthews, 1989). In collaborative learning, students learnt from each other within the group.

The coverage of the first problem statement was quite wide, including sample preparation & pre-treatment, Ultra Violet and Visible Spectrometry, and Atomic Absorption Spectrometry. An intensive literature research was required and information-processing skills were essential. The second problem statement covered Gas Chromatography & High Performance Liquid Chromatography but the deep learning of the content was much more difficult to achieve than with the first problem. Reading and summary skills were important to understand the theories and solve the problem given.

Assessment

Students were assessed according to the following criteria:

Class participation	5%
Laboratory work	25%
Laboratory test	10%
Tutorials / Assignments	30%
Term test / Quizzes	30%
Total	**100%**

For class participation, tutors looked into students' punctuality, participation and willingness to cooperate in the group work. Students were expected to complete the experiments given in each laboratory session and their competency & effectiveness in carrying out practicals were assessed. A written laboratory test was given to students at the end of the semester to evaluate their understanding of theories learnt in self-directed learning and practicals. Students were guided and monitored by tutors through question and answer sessions during facilitated discussions. A group report was submitted at the end of each assignment. Two peer assessments were done to differentiate students' performances in their PBL groups. Two term tests were given to measure the depth of students' understanding of the topics learnt as well as to provide feedback to lecturers.

Instruments Used

In order to assess students' information-processing skills, various instruments were used. A short Q & A session was conducted for every PBL group during facilitated discussions to monitor students' information-processing skills. Students were assessed once a week and the level of difficulty of questions prompted by tutors increased over the period of each problem statement. Most of the students improved in their information-processing skills. Spokespersons from each PBL group shared their findings or problems and facilitators gave their comments or feedback to students at the end of each facilitated discussion.

Peer assessment was conducted after each problem statement to differentiate individual efforts in the group during the self-directed learning sessions. The form was specially developed by ITAS specialist team. The assessment criteria are as follows:

- effectiveness of team work
- responsibility, independence and contribution
- information processing skills
- problem solving skills
- interpersonal communication skills

Two student evaluations were carried out through out the whole semester to monitor students' performances during their learning process using the school's programme evaluation first developed by the Chemistry Team. There were three sections in the form and students were expected to complete all questions. Students were required to give feedback on problem statement, learning process, and open comments on the learning approach or team work.

FINDINGS AND DISCUSSION

Results From Term Test

The results from the term test for both the control group and the experimental group were compared. The percentages of B and C for the experimental group were much higher than those of the control group, with an increase of 22% and 18% respectively. The average mark for the experimental group was 12 marks higher than that for the control group. These findings were extremely encouraging for the tutors for the following reasons:

- The experimental group had to rely very much on self-directed learning and the tutors' expectations of their learning were also much higher.
- Even though the level of difficulty for the two term tests was similar, the term test for the experimental group was wider in scope as one more topic was covered.

Detailed Results of the Experimental Group

Table 3 shows the results for all the components assessed for the experimental group. As can be seen, the students were consistently good in all aspects of the course.

Table 3
Summary of the experimental group's performance in different components

	Lab work (25%)	Lab test (10%)	Tutorial / Assignments (30%)	Term test/ Quizzes (30%)
% of A	1.9	19.4	3.7	6.5
% of B	24.1	22.2	28.7	18.5
% of C	45.4	25.0	46.3	31.5
% of D	21.3	21.3	19.4	36.1
% of F	8.3	13.0	2.8	8.3
Average	15.9	6.4	20.0	18.6

Comparison of Overall Statistics for Both Groups

A comparison of the overall statistics for both groups is shown in Table 4. Once again, the performance of the experimental group was better than those of the control group. The percentages of A and B were higher, with an increase of 2% and 8% respectively and with a higher standard deviation. It has been argued that with emphasis on group work, students' grade would tend to cluster, it is not so in this study. The results in this study show that with careful introduction of individual components into the programme, the grades were still very much differentiated.

Table 4
Overall statistics as compared with the two groups

Subject	**PIA**	
Two studied cohorts	**Year 1998**	**Year 1999**
Approach	Partial PBL	Full PBL
% of A	1.7	3.7
% of B	12.5	20.4
% of C	67.5	49.1
% of D	18.3	25.9
Average mark	64.2	64.1
Std. deviation	5.8	7.5

Programme Evaluation

Programme evaluation forms administered at the end of each problem statement yielded the results shown in Table 5.

Table 5
Evaluation on students learning process

Item	**Percentage**
Worked hard to understand the subject	98%
Attentive in class	98%
Came prepared for class	95%
Process helped me to learn better	85%
Process allowed me to contribute ideas	91%
Process allowed me to be creative	85%
Members helped each other	86%
Process helped me develop team skills	88%

Of particular interest would be students' response to the item about coming prepared for class. In the traditional mode, the percentage would have been about 50 – 60 %.

The lecturers were also consistently rated as enthusiastic & enjoy teaching (100%), as encouraging & approachable (97%) and being able to present subject materials in an interesting and stimulating way (98%).

CONCLUSIONS

The teaching team for 'Principles of Instrumental Analysis' (a subject for year 2, semester 2) considered improvement in student learning a primary goal for lecturers and took on the task of planning, implementing and evaluating an instructional programme using the PBL approach for the subject. The long period of planning and preparation was considered time well spent in view of the rewards in terms of better student learning among other things. Just as the students embarked on a journey of discovering and testing knowledge in their groups and by themselves, the teaching team members became more aware of their own teaching style and the impact it had on the students. Against this background of academic learning, both students and tutors learnt from each other. The subject team also learnt to overcome obstacles and differences through this experience. The end result of this honesty towards each other is the students' increased level of enthusiasm towards their own learning and markedly improved student performance in the subject. For the teaching team, the very encouraging student evaluation of the programme and tutors' teaching served as a great source of motivation for tutors to seek continual improvement in their profession.

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