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A Comparative Study of Problem-Based and Lecture-Based Learning in Junior Secondary School Science

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Abstract The purpose of the study is to compare problem based learning (PBL) and lecture-based learning (LBL) in Hong Kong secondary students' science achievement. Secondary One students were divided into two groups: group A (n=37), was taught two topics: "Human Reproduction" and "Density" through PBL; group B (n=38) was taught the same topics by LBL. Multiple choice questions and short structured response items were used to assess students' academic performance. Pre and post tests were categorized into three domains: knowledge, comprehension and application according to Bloom's Taxonomy (Bloom 1956). The results of this study suggest first that PBL is at least as effective as LBL in gaining the knowledge required to achieve the syllabus' learning objectives; secondly, the PBL group shows a significant improvement in students' comprehension and application of knowledge over an extended time. Seemingly, PBL is favored for knowledge retention compared to a more conventional teaching approach, by these early adolescent children in Hong Kong. An ongoing longitudinal study on students' interactions will further determine whether students taught through PBL develop improved learning in relation to high order skills, in a local situation which still tends to focus on factual recall but where higher skills are being demanded by systemic reform.

Keywords Comparing teaching strategies · Learning environments · Problem-based learning · Secondary science

Introduction

Secondary (High) School Teaching in Hong Kong, a Characterization

Hong Kong's schooling system is modeled upon that of its former colonizing power, the United Kingdom. However, as that country's school system moved towards a non-selective

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approach in the 1960s, and then to 11 years of compulsory schooling in 1972, Hong Kong lagged behind and today has an elitist system, based on selection of students at age 11 into three secondary (high) school types; bands 1, 2 and 3, for a minimum of three post primary years. However, in such an elitist system with a strong Chinese ethic of formal education, by the mid 1980s almost no students left school until they had completed 11 years of schooling, with the first public examinations at the end of "Secondary 5" at about age 17. Nine years compulsory schooling began only in 1978, hence most parents of children in school today were schooled in a system with many teachers who were not university graduates, and many of those had no formal pedagogical professional training. Secondary schools follow rigid syllabuses, laid down by the Hong Kong Education and Manpower Bureau (EMB). The usual emphasis is upon the learning of prescribed content by formal lecture style delivery, supported by teacher produced "notes" to be learned by rote. Class sizes of 40–45 students are normal.

Since the late 1980s attempts have been made to improve the system by introducing somewhat piecemeal curricular changes, (e.g. Hong Kong Education Commission 1986). However, in 1998, after Hong Kong had become a Special Autonomous Region of China, a commitment to curricular change was given. This will come to fruition in 2009 when 9 years of compulsory education will be replaced by 12 years, as is more usual in well developed economies; and rigid syllabuses will be replaced by curriculum frameworks so that more flexible school-based curricula may be developed. The blueprint for this change can be found in *Learning to Learn, 2000* (Curriculum Development Council 2000) which explicitly requires a number of "generic learning skills" to be taught to students, through all school subjects, including:

Creativity	Critical thinking	Collaboration
Communication	Information technology	Numeracy
Personal management	Problem solving	Study skills

Meanwhile, in some more far-seeing schools, styles of teaching are under intensive review, and approaches antithetical to lecture-based learning, such as project learning, and other constructivist approaches are being encouraged. Parents, and more conservative teachers and school principals are suspicious of such approaches, fearing that examination results, the keys to tertiary education, will be adversely affected. Interestingly, these approaches once deemed difficult or impossible by teachers whose own understanding of their subject disciplines was marginal, are now being encouraged by EMB. This paper reports a small study which seems to offer encouraging evidence for teachers to move towards such alternative teaching styles, and to reassure parents that their children's future academic success will not be jeopardized by such changes in teaching strategies.

Background

The study was undertaken as part of dissertation requirements for the degree of Master of Education in Science Education at the University of Hong Kong. It is the result of about 6 months of action research with two classes, both of them taught by one of the authors, who is a biology graduate with seven years' teaching experience in integrated science at junior (middle) secondary school level, with biology at senior secondary (high school) level. He has typically taught using a constructivist framework (*sensu* Matthews 2000.) but using a lecturing style augmented with probing formative and summative questioning.

Practical work, as defined by the syllabuses, usually of an illustrative kind, not requiring hypothesis formation and genuine experimentation, is also undertaken according to syllabus requirements.

For this study, two parallel classes having similar intake abilities were chosen at Form One level (aged 12). These students were from a heterogeneous socio-economic background and a middle ability level as defined by Hong Kong's three band selection system for students moving from primary to secondary schools. The school is co-educational, with approximately balanced numbers of boys and girls in each class.

What is Problem-Based Learning (PBL)?

Problem-based learning, (PBL), as an instructional model is receiving increased attention from educational practitioners. The model has developed rapidly in medical school programs since 1980. It is characterized by students' working in small groups to increase knowledge and develop understanding by identifying learning objectives, engaging in self-directed work, and participating in discussions (Barrows and Tamblyn 1980). More or less well structured problems act as focused stimuli for student learning in the model (Boud and Feletti 1997). On the other hand, a lecture-based approach (LBL), which is more common in Hong Kong secondary school teaching, is characterized by teachers' verbally transmitting information directly to large groups of learners who are then assessed mainly for recall ability (Fitzgerald 1997).

In medical education, PBL has been successfully implemented and demonstrated to have favorable outcomes (Bickley et al. 1990; Colvin and Wetzel 1989; Donner and Bickley 1990, 1993). Studies seem to show that PBL is more effective than conventional approaches in developing greater student motivation, breadth of interest, learning satisfaction, confidence with clinical functioning, knowledge acquisition, use of a variety of learning resources and self-directed work (Cariaga-Lo and Encarson 2001; Colliver 2000; Finch 1999; Hmelo 1998; Kaufman and Mann 1999; Norman and Schmidt 2000; Rideout et al. 2002; Willis et al. 2002). Many of these attributes are sought by the current reforms in the secondary school curriculum in Hong Kong, *post* 2000, hence it is timely for the Region, and of pedagogical value for teachers generally to examine whether younger and less able students than those in medical schools can benefit significantly from the application of the PBL model. PBL has a variety of ways in which it can be implemented; the four step model described below was adopted for this study.

Problem-Based Learning and Science Education

For science education, PBL is actually not new at all. In fact, school science education began to investigate the implementation of problem solving components much earlier than medical education. As early as 1938, Dewey had already emphasized the necessity of teaching science through problems that were relevant to students, using problem solving instructional strategies. Gagne (1965) also agreed that science concepts learned through problem solving were more meaningfully learned. A later report from Greeno (1978) showed that when teaching emphasizes a discovery oriented problem solving approach, students are likely to achieve greater problem solving skill development. More recently, some of the limited studies concerning science education seem to support the effectiveness of PBL for individuals' learning outcomes (BouJaoude 1992; Cavallo and Schafer 1994; Geban et al. 1992; Jones 1996a; Saunders and Shepardson 1987). Some research evidence

(Heyworth 1998; Huffman et al. 1997) has shown that explicit teaching of problem solving processes in science classes improved students' problem-solving skills, cognitive development and science achievement. Furthermore, Checkley (1997) asserted that the best way to learn science seems to be to offer learners opportunities to solve challenging problems. According to Webb (1999), science competency and literacy are relatively poor among high school students. It is suggested that PBL may become an effective method which could improve competency. A recent study from Greenwald (2000) describes PBL as a powerful vehicle for inquiry-based learning in which students use an authentic problem as the context for an in-depth investigation. Goodnough and Cahsion (2003) agree with Greenwald that students learning through PBL actively explore open-ended problems and offer alternative solutions.

In the context of Hong Kong school science education, the development of PBL, especially with respect to a comparison between the results of PBL and conventional learning has still not been attempted at any level. Locally, PBL is still not accepted as an educational strategy except in one medical school, and in a small number of other tertiary programs. In general in schools there is still considerable reluctance to carry out substantial pedagogical reform. A situation in which the curriculum in Hong Kong was characterized by an emphasis on factual knowledge transmission (Morris 1990) still exists in 2008. As admitted in previous studies (e.g. Herreid 2003; Jones 1996b; Mpofu et al. 1998; Wood 1994), implementation of PBL requires effort and commitment from both teachers and students. These studies come to the conclusion that a considerable resistance is to be expected when beginning to develop PBL in science education or other areas. Assessment of short and long-term outcomes to demonstrate that the teaching method is achieving its goals for students is needed to reassure stakeholders that the effort devoted to PBL is worthwhile.

In this study there are two main research questions:

1. What is the immediate impact of lecture-based compared with problem-based pedagogy on students' learning outcomes (knowledge acquisition, comprehension and application of knowledge) as measured by pre- and post-testing?
2. Are there longer term effects of these two pedagogies on students' learning outcomes as measured by delayed post-testing? i.e. does one sustain learning better than the other.

Study Design

Participants

Two classes of 38 and 40 Form 1 students (age 12–13 years) were chosen. Each class had approximately the same number of girls and boys. Average percentage scores of The Pre-Secondary 1 Attainment Tests were 63 and 59 respectively (4% difference). Hence the general ability level of the groups could be considered equivalent, and corrections could be made in any measured differences between them, before statistical testing, in the final data analysis. The smaller class was designated as the PBL group, the larger one was offered LBL. Two topics from the Junior Integrated Science syllabus (Curriculum Development Council 1998) were chosen: the first, "Human Reproduction" having a high intrinsic interest; the second, "Density," being a topic of low interest as seen over several years' teaching of students. In teaching this topic over the years it seems that students have little understanding of its value in everyday life unless applications are taught. These are usually given as a list of examples after the theory has been covered.

Neither group of students had ever been exposed to problem-based learning before but, since they were new to the secondary (junior high) school, their expectation of new approaches, and their capacity to adapt to them, may have been higher than for more senior years. Since all of their teachers were new to them, they might be expected to have limited preconceptions of the teachers' styles, nor should their concepts about normal classroom interactions be pre-determined. Furthermore, secondary schooling is characterized by a change from small numbers of teachers, each teaching across a range of subjects, to many teachers each teaching a single subject, so variability of approach is a matter of routine for reception class secondary students who might express their attitudes towards novel teaching approaches in a less biased way than students in higher forms. Hence research with reception classes might yield more objective outcomes, provided that the intellectual demands placed on them by alternative learning tasks are reasonable. Another related piece of research (Wong and Day 2006) illustrates that students actually expressed preferences for learning through PBL.

One class was taught two topics from the syllabus using the researcher's habitual lecturing, prescribed practical and formative questioning approach, the other was offered problems of a loosely structured nature, (see below) which sought to stimulate the students to examine the content of those topics by themselves, with the teacher acting as a guide and facilitator only. The sequence of problem-based learning suggested in many research studies, (e.g. Stepien et al. 1993), was followed. Broadly the following four steps ensued:

1. The problem, constructed by the teacher to achieve the curriculum and learning objectives, was presented to students (see below).
2. Students were left, in groups of five or six, to carry out initial analysis of the problem, with guidance in process but with no content-knowledge instruction from the teacher. Work consisted of defining the problem, discussing, brainstorming, creating need to know lists, posing direct and rhetorical questions, deciding what to research and how to proceed. Students were given record sheets to guide their research, and these offered the teacher understanding of their progress at the end of each lesson.
3. Research time was given for gathering information, evaluating it, discussion among group members, building models, and creating group "products" which might be written or graphical solutions to the problem.
4. Groups then reporting their findings, communicating information as required by the problem, with conclusions or recommendations to the teacher and their peers.

PBL students were offered opportunities to use the internet, the school library and for one topic supervised laboratory facilities, to investigate whether their ideas were supported by empirical evidence.

Students' prior knowledge about the topic was examined by a structured pre-test containing multiple choice and short answer questions. Immediately after the teaching, a post-test was given, and about two months later a delayed post-test was administered, to examine retention of ideas. The pre-test and post-tests were structured so that questions of different levels of thinking, according to Bloom's taxonomy: recall, application and analysis were included. Examples of pre- and post-test questions are included (in Chinese, with English translations by the authors) in Appendix 1. The pre- and post-tests used the same questions, but they were re-arranged so that students might be less likely to recall their exact responses. It was also considered that, after 8 weeks, students would be unlikely to recall their exact responses unless they understood the concepts. In any case, gains in scores from the previous iteration of the test, for each group, would be expected to be similar for both PBL and LBL groups if memory alone was a factor.

Before each topic was introduced the PBL students were briefed about the processes of PBL. Briefing consisted of explanations of the processes, the roles and responsibilities which might be assumed by group members and distribution of study aids to help them organize their "needs to know", and information having been researched. These organizers were subsequently also useful to the teacher in gauging how effective students had been in achieving the learning objectives at each stage, prior to formal testing. Students were also made aware of some of the difficulties they might encounter in working in groups but also of the possible benefits of working in this way for their future study. They were given the first problem during the latter part of their first semester. The LBL group received the researcher's lecture-based teaching, including some probing questions to elicit prior knowledge and allowing interaction between teacher and students. This style tends to discourage student–student interactions in favor of a conventional orderly class-teaching environment. Both groups were asked to complete homework, usually research for their following PBL session for the PBL group, and reading or writing tasks from the textbook for the LBL group. Since more than 80% of students in Hong Kong have access to the internet at home, and 100% have access in schools, both groups had the opportunity to do further research on the topics, but only the PBL group was given specific lesson time to work in the school's internet learning centre and encouraged to do such work.

The problem on Human Reproduction (Fig. 1) was judged by an expert panel, including a medical doctor, to contain cues requiring students to research all aspects of the syllabus related materials, hence achieving at least the same learning objectives as their peers receiving text-book based lectures and questioning. The learning objectives related to this problem are as follows:

Students should:

1. appreciate and understand how a new life is born
2. describe the various changes at puberty and the secondary sexual characteristics of the two sexes
3. identify the different parts of the male and female reproductive systems
4. acquire some knowledge about the menstrual cycle
5. acquire some knowledge about pregnancy
6. recognise the responsibilities of parenthood
7. acquire some knowledge about the need for family planning and various methods of birth control
8. develop a positive attitude towards sex
9. recognise the responsibility within relationships and be able to make judgment on appropriate behaviour in relationships
10. appreciate the value of life and develop a positive attitude towards it (Curriculum Development Council 1998)

The teacher asked the PBL group to make lists of "facts they might need to know", an "action plan" for their research (finding out), and to write "possible solutions" concerned with the problems. The teacher moved among the groups to be certain that the students were considering things that could lead them to the intended content knowledge or objectives intended by the problem. At times, the students were given access to a computer laboratory to research internet based resources. The groups were expected to review and revise their solutions and synthesize information from various sources. After that, each

a

Case 1 The Mystery of Sterilization

Mr. and Mrs. Chan have been married for two years and have sexual intercourse regularly. They are hoping to have a baby as soon as possible but they find no sign of pregnancy throughout these years.

- Imagine you are their Obstetrics and Gynecology specialist doctor, give them advice about why they still do not have a baby.
- Explain the process of conception to Mr. & Mrs. Chan and explain to them how to improve Mrs. Chan's chances of pregnancy.

Things to know:

Mr Chan is a cook who works five days a week in a very hot environment while Mrs. Chan is a housewife.

As a cook, Mr. Chan always wears tight jeans and T-shirts whilst working close to hot cooking ranges

b

Case 2 Birth Control

Mr. and Mrs. Lee are farmers in a remote area in China and have been married for 10 years. They have not been educated in schools and have no knowledge about contraception at all. They have regular sexual intercourse. They already have five babies and they do not want to have any more as they are not able to afford the cost of raising so many children.

Explain to them the alternative types of birth control and recommend those that they will most likely succeed with.

Fig. 1 Two PBL cases for "human reproduction," presented to the PBL group (originally in traditional Chinese characters)

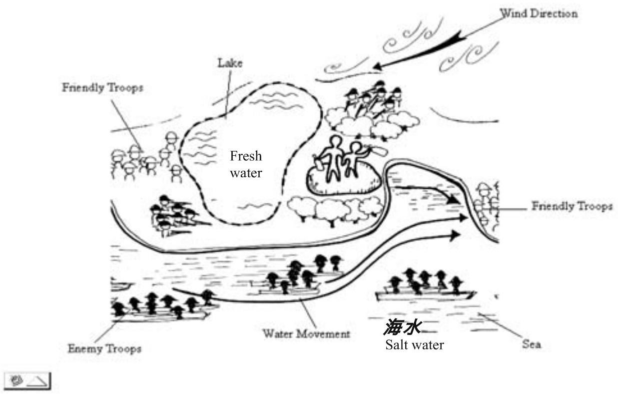
group was randomly invited to give a short presentation about how they had intended to solve each case, in front of the remainder of the class. Groups interacted with question and answer sessions following the presentations.

The problem on Density, (Fig. 2) and the associated lecture based teaching to the LBL group were presented to the students in the mid-part of the second semester. Hence the students had known their teacher, the researcher, for longer, and both groups had experienced his lecture-based teaching about other topics from the syllabus following the Human Reproduction topic. In this second instance, in addition to the problem, PBL students were given access to a science laboratory and provided with items as noted in the "instructions" below the task. Gallagher et al. (1995) noted that problem-based learning in science should perhaps allow students the opportunity to investigate their solutions to appropriate problems empirically. This assertion was investigated during the "density" topic.

The groups were expected to find the relationships among density, mass and volume by designing simple experiments. On the other hand, the LBL group was told the relationship first, followed by some simple practical work which demonstrated that the relationship of

Case 3 May Day!!!

Imagine that you are a soldier leading troops which are accidentally surrounded by the enemy. You need to pass an important 'May Day' message to your friendly forces and that is the only way you can escape. A reference map is given below. *Black hat figures are enemy troops, white ones are friendly*



You only have **some plastic bottles, some sand and pebbles** in your isolated area**.** You have to pass the 'May Day' message using the bottles and hope that your fellow defenders can find it. However, you need to pass the bottles **just under the water surface** so that your enemies cannot see them; otherwise, your troops would all be killed by enemy guns.

Instructions: Use the resources provided in the isolated area: plastic bottles, sand and pebbles and notice the geographical factors: lake(fresh water淡水), sea water(海水), wind direction and water current.

Fig. 2 A PBL case about "density," presented to the PBL group (originally in traditional Chinese characters)

these three parameters was exactly what they had been told. The rather limited curriculum objectives, in the context of the problem above, related to density of solids and liquids, from the integrated science syllabus are as follows:

Students should:

- acquire some knowledge of density

More able students should:

- be able to explain the greater densities of solids when compared with liquids or gases using the particle model (Curriculum Development Council 1998).

Statistical Analysis and Results

The pre-test, post-test and delayed post-tests for each topic examine factual recall and also the students' ability to apply their knowledge in offering advice on contraception in one case, and explaining floating and sinking phenomena in the other, in ways similar to those

Table 1 Changes for the LBL group between topics (ρ<0.05)

Change in scores between two topics LBL group	Sexual reproduction in humans	Density	Mean difference	Standard error difference	ρ
Pre-test to first post-test—mean marks	+50.0	+46.0	4.05	3.9	<0.30
Percent change—short term improvement[a]	+25.0%	+9.0%	− 0.10	0.04	<0.01[b]
Percent change—long term improvement[c]	+42.0%	+35.0%	0.07	0.07	<0.32

[a] Short term improvement=change from pre-test to post test

[b] Significant change

[c] Long term improvement=change from pre-test to delayed post test

about which the problem requires them to examine. As stated above, the equivalence of PBL and LBL groups academically was considered before the study began, but additionally, the results of the pre-tests for the two groups were compared statistically (Tables 1 and 2).

The scores for the PBL group were very similar to the LBL group for the Reproduction topic, so the difference indicated by students' school entry level test scores was maintained in the subject specific pre-test. The difference was not statistically significant at ρ<0.05. For the Density topic, the LBL group showed significantly greater pre-test knowledge and understanding than the PBL group, but as can be seen in Table 1, this difference was significantly eroded from the first post-test onwards. The test items were not validated statistically, but since the same test was used for both PBL and LBL groups, cross-sample item consistency was assured.

Changes between students' tests (pretest, immediate post test and delayed post test) in both PBL Group and LBL Group might be positive or negative, so two-tailed tests of statistical significance were used. Data were analyzed using SPSS 12 (SPSS Inc. USA). For all tests, the conventional ρ<0.05 level of probability was chosen as the level of rejection for the associated null hypotheses, "that no difference should exist between scores of equivalent tests if the teaching approaches were equivalent in effectiveness." Tabulated results indicate statistical significance at or beyond this probability level only.

The mean marks for the pre-test and immediate post-test (Tables 1 and 2) in the PBL Group were quite similar to those in the LBL group, thus both groups of students showed similar increases in knowledge acquisition but there was no significant difference between the groups. The PBL group performed better in the second topic "Density" compared to the topic "Human Reproduction" studied earlier. However, the mean values for short-term

Table 2 Changes for PBL group between topics (ρ<0.05)

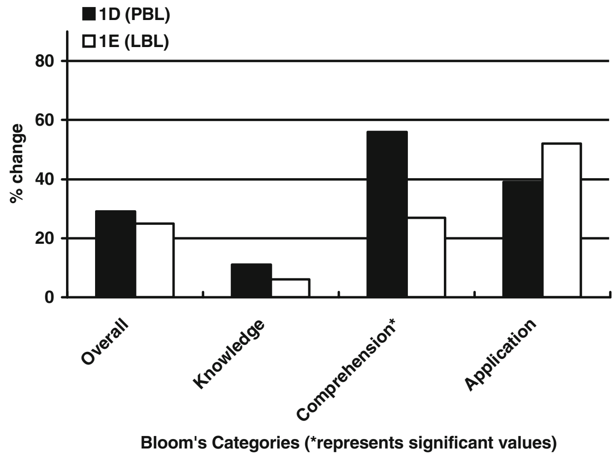
Change in scores between two topics PBL group	Sexual reproduction in humans	Density	Mean difference	Standard error difference	ρ
Pre-test to first post-test—mean marks	+44.9%	+34.4%	10.45	3.93	<0.01[a]
Percent change—short term improvement[b]	+29.0%	+60.0%	−0.31	0.13	<0.02[a]
Percent change—long term improvement[c]	+79.0%	+162.0%	−0.83	0.23	<0.00[a]

[a] Significant change

[b] Short term improvement=change from pre-test to post test

[c] Long term improvement=change from pre-test to delayed post test

Fig. 3 Short-term improvement for human reproduction problem (pre-test to post-test)

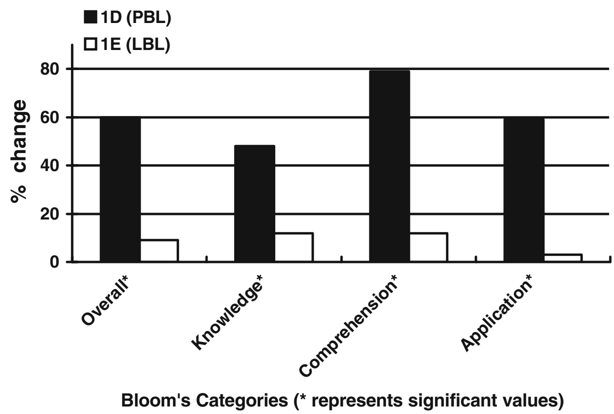


improvement and long term improvement in the PBL groups were significantly improved in each of Bloom's categorizations in the PBL group compared to the LBL group (Tables 1 and 2).

In questions relating to "Human Reproduction", even though application level test results and overall scores of the PBL students are not significantly different from the LBL group, the students tended to perform better than the LBL students (Fig. 3). This suggests that PBL is at least as effective as LBL in learning the specified science content. For "Density", the test results for overall scores and in all categories are significantly better for PBL than for LBL students (Fig. 4).

There may be more than one explanation for the improved outcomes in the second PBL task compared with the first. First, the students' PBL experiences in the first encounter may have improved their ability to perform in the second. As the students receiving PBL were separated into groups, the sense of collaboration and communication may have improved when a second opportunity to use PBL was offered, compared to their usual practice where interaction in a teacher led class is inhibited by the preference of the teacher for a quiet class. Secondly, after the students designed a 'submarine', in the density investigation they were given chances in the laboratory to try the product's buoyancy and to investigate all

Fig. 4 Short-term improvement for density problem (pre-test to post-test)



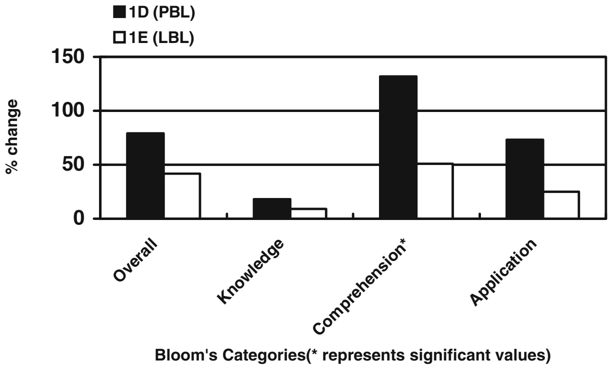


Fig. 5 Long-term improvement for human reproduction (pre-test to delayed post-test)

possible factors which led it to float. The observed effectiveness of PBL may be enhanced by opportunity to design experiments. Such kinds of trials offer constructive experiences which in turn reinforce learning to assess the relationships between mass, volume and density. The PBL learning cycle may be enhanced if students engage in some practical sessions. In addition this result also provides evidence that students are not natural PBL learners, especially if taught by antithetical approaches during their primary school years. It may indeed be important to let the students gain some PBL experience in pilot topics before implementing PBL more fully in the curriculum. This too has been seen before by Whitehill et al. (1997) at the tertiary level in Hong Kong.

Long-Term Improvement for Density (Pre-Test to Delayed Post-Test)

The results from the delayed post-testing suggest that PBL may have longer-term effects on students' learning outcomes. For both topics, PBL students performed significantly better than LBL students in nearly all the categories of questions and in overall scores in the delayed post-test (Figs. 5 and 6). The outcomes are actually quite parallel to previous studies with older students, which suggest that PBL has a positive effect upon knowledge retention. As PBL requires students to learn in a constructivist manner, not simply recalling factual knowledge, it is possible that the students may have a better understanding of what they have learned during the process which is more readily recalled in later tests.

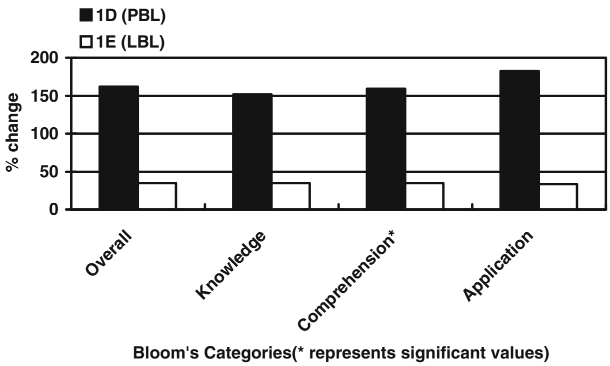


Fig. 6 Long-term improvement for density (pre-test to delayed post-test)

The data shows that both PBL and LBL groups performed well in all categories of questions and overall scores in the “Human Reproduction” topic, whereas in the “Density” topic, PBL was apparently superior in learning effectiveness. A possible reason for this difference, apart from those noted above, may be that the students applied prior knowledge learned from primary education and from informal sources in the case of Human Reproduction, whereas Density is not considered in the Hong Kong primary science part of the General Studies syllabus and it is rarely encountered explicitly in informal situations. As there are only two topics in this study, it is not possible to suggest how the nature of a topic may influence the performance of students. A further research question might be to examine more contrasting science topics (formally or more informally learned) which could provide a clearer understanding about whether the nature of a topic would influence the effectiveness of different instructional styles.

In the present study, PBL components replaced substantial content of two topics of the secondary Form One Integrated Science Curriculum in Hong Kong. Such a method of implementation seems to be supported by Grow and Plucker (2003) who contend that PBL can be put into practice in existing lessons without redesigning the science curriculum. These initial results are encouraging. They might reassure science teachers, especially those who have been taking relatively more conventional teaching approaches, to add PBL to their teaching repertoire in a progressive manner with the possibility of improved learning outcomes beyond knowledge recall. An additional aspect of the study previously presented at the 6th International PBL Conference, (Wong and Day 2006) showed that student satisfaction with the learning style developed by PBL was significantly greater than their satisfaction with LBL particularly because PBL allowed greater student co-operation in the learning process.

The test data suggest that students learn at least as well by PBL as by LBL. Significantly their retention and higher order thinking skills (Biggs 1987 and *sensu* Bloom 1956) are significantly improved when PBL techniques are employed. A second claim from published PBL studies at tertiary level relates to the improved learning co-operation and sense of inquiry generated by PBL. Hong Kong schools have been dominated for many years by teacher-talk, an approach characterized by lecture-based learning, and students have been further deskilled in learning by a culture of note giving rather than note taking. In other words teachers prepare written précis of the content to be learned rather than expecting such ‘distillations’ to be done by students as part of the learning process. Furthermore, worksheets using cloze type gap filling are often deployed, apparently with the intention of the students filling them in. In practice, either because of supposed language difficulties in classes taught in Cantonese but examined in English, or simply because students are allowed to be indolent, the teacher often supplies the words for completion, so that the students are merely required to transcribe the teacher’s answers, and then to learn them by rote for later examination. This de-skilling has been described by as “learned helplessness” (Petersen et al. 1995) and it is entrenched from the earliest days in primary (elementary) schools. More recently qualified teachers are emphatically discouraged by their teacher education from employing such teaching approaches, however if they join a school where the culture is embedded, they may be accused by students and parents of being unhelpful, and in a system of contract renewals, they may well not be re-engaged, hence they fall into strategic compliance with the culture. It seems to be quite difficult to break the cycle.

While curriculum reform has given frustrated teachers the opportunity to break the mould of compliance, it is important to show conservative stakeholders that development of these skills provides both better learning outcomes and more satisfying learning environments for the students.

Conclusion

In Hong Kong, educational reforms highlighting the development of higher order skills' and abilities (Biggs and Collis 1982; *sensu* Bloom 1956) have been intensive in recent years. The above findings offer evidence that PBL, as an instructional model, could be effective in achieving higher learning goals in junior secondary science education. Moreover, this study seems to offer evidence for the value of PBL in learning for test success. In PBL, the students seem to be motivated by their own curiosity when presented with interesting problems, they might have both satisfaction and pressure from a task to be completed within a prescribed period of time. In LBL they were motivated by the teacher's ability to stimulate their interest by charisma and the potential challenge of questioning. There seems to have been little intrinsic motivation.

The present study seems to show that the accepted effectiveness of PBL in tertiary programs can be observed in junior secondary (middle school) science classes in a Hong Kong secondary school and that students learning through PBL have better retention when compared with peers taught using Hong Kong's traditional style. The present small scale study is leading to further examinations of PBL in local science teaching to attempt to demonstrate consistent achievement of better outcomes. In some ways this study mimics one published recently by Senocak et al. (2007). However, there the subjects were aspiring chemistry teachers at tertiary level. It is considered that the present study is particularly useful as it seems to indicate that PBL teaching strategies provide gains in learning outcomes for much younger students of average ability. Wong and Day (2006) have also shown that PBL provides a learning environment which is preferred by the students, and which provides them with metacognitive gains for their future academic development.

Appendix

Appendix 1. Types of questions in pre- and post-tests for both PBL and LBL students

Reproduction topic

1. **注意：**根據以下資料回答下面兩個問題。

According to the information provided in the diagrams below, (*well known biology text diagrams, not shown*) answer the following two questions. *(recall of knowledge)*

1. 精子在哪裏產生？

Where are sperms produced?

A. w B. x

C. y D. z ☐

(questions 2 & 3 application of knowledge)

2.a. 陳先生自小對**膠乳敏感**， 為甚麼這樣會妨礙他避孕?

Mr. Chan is sensitive to LATEX since his birth. How could such a problem affect him if he and his wife wanted to avoid having more children?

b. 承上題，陳先生決定永遠不要和太太生育，請**建議一個手術**給他 ；並解釋為何此手術可以令他和太太進行性行為時，永遠不會懷孕。

Mr. Chan and his wife decide not to have any more children, **SUGGEST AND EXPLAIN** a method of contraception he can use so that he can never makes his wife pregnant in the future, when having sexual intercourse with her.

細閱下文， 並回答下面問題。

3. Read the paragraph below and answer the following questions.

陳先生，三十 歲， 廚師。 他經常於 *35°C 高溫下工作12 小時。 由於工作關係，他常穿牛仔褲。 近日， 他工作的餐店生意不好， 老闆警告任何員工如未能符合他定下的工作時間和 高溫下工作要求， 將會被辭退。*

經過醫生檢查，他被告知證實不育。 報告顯示他的精子有可能出現問題。 假切你是他的家庭*醫生，按以上資料，* ***建議兩個精子*可*能出現的問題*** **；並提供一個幫助他的方法。**

Mr. Chan is a thirty-year old chef who needs to work for twelve hours each day in a 35° C environment. For comfort, he always wears jean to absorb the sweat. Recently his restaurant faces financial crisis and his boss warns that workers who cannot accept these working conditions will be dismissed.

After a medical check up, Mr. Chan is told by his family doctor that he is impotent. His medical report reveals that he probably has some problems in relation to his sperms. Imagine you are his doctor, by using the information provided above, suggest two possible problems which might affect his sperms and suggest one way to help him.

兩個精子*可*能出現的問題

a.

b.

一個幫助他的方法

Density topic

1. 很久以前，在一條古老的村落，一名賣炸雞的小販投訴被小偷偷錢。士兵捉拿了三名嫌疑犯讓國王發落。國王思索了一會，下令三名疑犯, 甲，乙及丙，用肥皂洗手（除去手上污垢）,把身上的銅幣分別放入三個盛有水的桶子內。不久，國王發現疑犯甲放置銅幣的水面浮現油蹟，便當場把他擒住。

A long time ago, a hawker in a small village, who sold fried chicken, reported to the police that all of his money(coins) had been stolen. The police arrested three suspects , A, B and C, and took them to the village head-man. He made A, B & C wash their hands with soap, THEN remove the money from their pockets, and drop the coins into three separate buckets of hot water. After a while, the head-man ordered the police to put suspect A into jail because he was the one who made the water oily, so he must have been the thief.
(application of knowledge)

a. 為什麼國王斷定甲就是小偷？ Why did the head-man say that A was the thief?

b. 試利用你對密度的知識， 解說國王的推斷。 Applying your knowledge of density, explain the head-man's decision.

2. 有一天，小華和小欣打乒乓球時，意外地把球跌進一個深一米的坑洞內，他們只有一個球，你會怎樣幫他們呢?

One day, while Siu Wah and Siu Yan were playing table tennis, one of them accidentally dropped the ball into a 1-metre deep hole.

(i) 利用關於密度或浮沉的知識，你會怎樣幫他們拾回乒乓球呢?

Using your knowledge about buoyancy and density, how can you help them to get back the ball? Explain your ideas *(Application of knowledge)*

(ii). 數天後，小欣同一位置跌了一個$2 硬幣，若用上述方法，她能否拾回硬幣？ 為什麼?

A few days later, Lily drops a $2 dollar coin into the same hole. Can she get back the coin using the same method as mentioned above, Explain your answer.

3. 下表列出一些物質的密度： The table below shows the density of some substances. *(application of knowledge)*

物質	密度 (g / cm^3)
W	0.89
X	1.26
Y	1.73
Z	6.45

(a) 表中哪些物質會浮在水面？Which of the substance(s) can float in water?

(b) 表中哪些物質會沉在水底？ Which of the substance(s) sink in water?

(c) 2 g 的物質 X 體積是多少？ What is the volume of 2 g of X?

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