AN EVALUATION OF A PROBLEM BASED LEARNING APPROACH TO TEACHING TECHNOLOGY

Ken Sutton, Anthony Williams, P John Williams.
Department of Applied Science and Technology
University of Newcastle
NSW 2308

Abstract

It is the purpose of this paper to present a rationale for using a PB
L methodology in technology
teacher training, including a historical background, a description of th
e present situation and theœidentification of possible future trends.   T
he PBL methodology developed for this project isœdescribed, with the tec
hnological context to which the PBL methodology is applied, namely solar
œenergy as the source of power for a commercially viable product. A mod
el has been developedœfor this project, including the strategies used i
n implementation, the stimuli used to sustain studentœinterest, and meth
ods of assessment. Evaluation deals with issues of student perception.

An evaluation of a problem based learning approach to teaching technology

This presentation will examine the Problem Based Learning (PBL) a
pproach to teaching inœtechnology education. Many educational methods a
re problem based, and they may have quiteœdifferent educational objectiv
es. That which they all have in common is the use of problems in theœin
structional sequence. The problems may be as diverse as a mechanical pr
edicament, anœunexplained phenomena, or patient symptoms.

In order to a ppreciate the need for the implementation of such
methodologies as the P BL methodœinto technology teacher
education, it is important to understa nd the historical
development ofœtechnology education, the forces that h ave shaped
it, the current forces for change, the demandsœupon the schoo l
systems and, consequently, the tertiary institutions training
teachers for theseœschools.

Technology education was introduced into the school system at
the turn of the Century. It wasœformed to meet the needs of a
fast growing manufacturing and industrial sector. The nation
hadœcome o ut of a depression and was going through a period of
boom or growth. Th e needs ofœindustry were mainly a semi
skilled trade based workforce. Th e secondary school
technologyœcurriculum was therefore based upon the tr ades that
were needed by the industries of the day. œThese included voca
tional or trade oriented skills such as drawing and benchwork

skills in b othœwood and metal.

Since the time of this introduction, there has been little
significant change in the content and theœform of technology edu
cation in secondary schools. Even at the end of the last decade,
it was stillœbasically skills centred with a focus on
replicating demonstrated skills and production of projects that
were primarily based on wood and metal.

During the 1980's, educ
ation became the focus of social attention. In general, there was a fee
lingœof concern about secondary school graduates. In order to identify t
he problems that existed and theœareas that needed development, a number

of studies were conducted. As a result of studies suchœas the Carrick R
eport (1989), the New South Wales Government released a White Paper titl
edœ"Excellence and Equity". This document was accepted by the Parliamen
t of New South Wales andœthe changes that it proposed are being implemen
ted. Technology education received specialœmention in the reports that w
ere developed in the 1980's and also in the "Excellence and Equity"œpape
r. It stated that technology education was not meeting the changing nee
ds of society. This isœreflected in a discussion paper on technology ed
ucation from the NSW Department of Educationœ(1988,1):

Technological innovation, application and change have not been
uniform. Recently, the rate of change has increased. New
technologies have proliferated as tec hnology hasœinteracted with
advances in scientific knowledge. The speed of the advance of
knowledgeœand the means to apply it have tended to ou tstrip the
ability of individuals and many socialœinstitutions to assimi
late both the nature of technology and the likely consequences of
itsœut ilisation. Technical change has apparently become almost
inexorable.

The Carrick Report (1989) acknowledged the need for changes to be
made in the manner in whichœtechnology education was taught.
This report s tated that "consideration may need to be given
toœincorporating technolo gical components into a wider variety
of appropriate subjects given theœp ermeating nature of
technology in contemporary lifestyles". In this way students
would be betterœplaced to appreciate practical applications of
technology (Carrick,1989,61).

Technology education is currently underg oing the changes
necessary to meet the demandsœassociated with technolog y
identified in the above reports and Government documents.
Briefly, the œcurrent trends in technology include :

1. The incorporation of a diver se range of technologies and a

variety of application of theseœtechnolog ies.

2. The methodology identified as appropriate for teaching these technologies is that of problemœsolving, or the design process.

3. The opportunity for the development of creativity and adaptability skills.

4. The ability of people to work together collaboratively in the problem solv ing process.

Technology education in secondary schools is undergoing a p eriod of significant change. It is,œtherefore, imperative that technolo gy teacher education adopt not only the technologies that haveœbeen iden tified as being important, but also incorporate appropriate methodologie s for theœinstruction of these technologies. PBL offers a number of asp ects of importance to technologyœeducation and it is because of these th at the project outlined in this paper has been developed.

The rationale for structuring a curriculum on PBL is to promote student centred inter disciplinaryœeducation as a basis for lifelong learning in professional p ractice. The professions that haveœimplemented PBL have in common ident ifying and trying to resolve 'problems' through variousœphases of carefu lly orchestrated activities. Attempt is made to simulate the profession al context inœwhich the knowledge is to be used.

Problems act as the st imulus and focus for student activity (Boud, 1991) in providing the opportunities for students to develop p rofessional behaviors. It isœgrounded on the belief that learning is mo st effective when students are actively involved, and learnœin the conte xt in which the knowledge is to be used.

Apart from the basic methodol ogy, there are other aspects of PBL that are relevant to technologyœeduc ators. Because it has been implemented in a number of contexts for some time, a body ofœresearch has developed relating to aspects such as the p sychological basis for PBL as both aœteaching and learning phenomena, ap propriate assessment methods, evaluation of the impact ofœPBL, and diffe rent teaching methods. Technology educators do not yet have as signific ant a bodyœof research upon which to draw.

Characteristic features of PBL

There are a number of common features of PBL, regardless of the spec ific methodology or the context in which it is applied. A summary of these features follows.

1. When promoting observational skills, it helps to use as many senses as possible, for example inœpresenting a situation, more than simply a wri tten description will assist in honing studentsœobservational skills.

2 . Using simulations or experience to simulate reality (which may be pro fessional practice). Theœsuccess of simulation methods depends on havin g clear learning objectives and appropriateœresources available to stude nts. A written description is the poorest form of simulation. Curricul aœusually have learning experiences which offer progressively more reali stic and complex situationsœmatching student skill development.

3. Stu dent collaboration must be encouraged in order to foster a supportive le arning environment.œGroups may be involved in brainstorming the nature o f a problem, identifying topics on whichœmore information is required an d will later become the focus of independent studies, explainingœnew ide as or reasoning how mechanisms work or systems interact.

4. Student di rected learning can be fostered by allowing student control over aspects of theœlearning process including setting goals and objectives, plannin g the learning timetable, choosingœwho to work with, deciding what and h ow they will learn, and how the outcomes will be assessed.

5. Independ ent study can be encouraged through what the students learn outside of c lass, forœexample professional literacy, finding and retrieving informat ion, goal setting, time management,œcritical thinking and self evaluatio n.

6. Students reflect on the learning process by thinking about their learning experiences as a wholeœ- what deficiencies there are and how t hese may be remedied, whether a learning plan was achievedœor how the go als could be more efficiently met.

Problem based learning models

Problem Based Learning, as Feletti (1993, 146) stated, is "...an

o rientation towards learning that is flexible and open and draws upon the varied skills and resources o f faculty and students." Thisœflexibility of PBL is one aspect of the l earning model that has application to technology education.œOne problem t hat does exist because of this flexibility is the ability to represent t he concept of PBLœas a model. Any model that is developed will relate s pecifically to the situation in which PBL hasœbeen applied. PBL, and va riations of the strategy, have over the last decade been extensively use dœin Medicine faculty's around the world, and for this reason many PBL m odels relate to these ares. œThe models shown in Figure 1 are drawn from medical education.

On examining these models it is not difficult to id entify a range of similarities between the PBLœmodels and the models of t he design process that technology educators have used extensively forœa n umber of years now. The models shown in Figure 2 are commonly used to r epresent the designœprocess.

Similarities Between PBL and the Design Process

As stated, there are a number of similarities between the two teachi ng strategies. Briefly these include:

1. A large number of phases or stages through which to pass du ring the project.

2. Both start with an identified problem or situation which directs the students area or context ofœstudy.

3. Student initia ted research is relied upon for the student to progress through the proj ect as wellœas for their own learning.

4. Both require high levels of s tudent initiative, students need to develop motivation andœorganisation s kills.

5. Both lend themselves to long term projects, PBL may be used o ver a short time frame but thisœdoes not detract from its ability to be u sed effectively over a longer time frame, as is usuallyœassociated with t echnology projects.

6. Both are open ended with regard to outcomes, all owing the student the opportunity to choose,œafter appropriate research, an outcome that interests them.

7. Observational skills are identified as having a high priority, especially in the initial stages duringœthe i dentification of the problem.

8. Student reflection is an important asp ect of both models, the student is encouraged to evaluateœfully the outc ome they have achieved.

These similarities indicate that both the desig n model and the PBL model are representative ofœappropriate methodologie s for technology education. The interest of this paper is in the applic ationœof the PBL model to technology education. The PBL model has a num ber of distinctive aspects,œand it is these that can readily and appropr iately apply to technology education:

1. A reliance upon group work. G roup work has become an important methodology forœtechnology education. T he ability of

individuals to work as a member of a group has beenœidenti fied as an important attribute, it requires a range of skills which incl ude, (a) an ability toœincorporate their personal skills into a group pr oject, (b) to work with others to identify andœorganise a range of tasks to be addressed by the group, (c) to persevere with teamwork in proble mœresolution, (d) to participate in shared learning exercises, and (e) e ngage in shared decision makingœ(Australian Education Council, 1992,19,2 0,24,30).

The ability of an individual to work as a group member is seen as im portant to the technologicalœworld. Technologically developed countries such as Japan an Sweden have used groups or teamsœas a strategy in solv ing technological problems whereas Australia is just beginning to apprec iate theœbenefits of using this problem solving strategy. The skills id entified in the Technology forœAustralian Schools Interim Statement (see above), acknowledge the need for individuals to be ableœto work effecti vely as team members.

Kennedy and O'Kelly (1991) established that stude nts, through involvement in group work, were œexposed to experiences tha t emulated the 'world of work'. The skills developed through groupœwork include communication skills, adaptability, listening skills and organi sational skills (Eckert,œ1991, 10-11).

PBL is based on the practice of using group work as a basic principle. Because of this use of groupœwo rk there is a range of benefits to be gained through the incorporation o f this strategy into theœtechnology classroom.

2. An emphasis on analy sis. Another characteristic of PBL that lends itself to technologyœeduc ation is the recognition of the skill of analysis. It has long been rec ognised that research hasœbeen an important aspect of the design process , what the PBL strategy does is to add emphasis toœthe area of analysis. The model in Figure 3 shows this emphasis on analysis in the overall process.

The PBL methodology encourages students to undertake in-depth a nalysis of the information theyœhave gathered as well as the information they have received in relation to the problem or situation. œThis empha sis on analysis is shown by the boxing in of this component on the model in Figure 2. œThis emphasis on analysis is needed in technology problem solving as it is too easy for students toœgather a great deal of inform ation during the research phase of problem solving, then simply useœthat information to support their original ideas. Through thorough analysis of both the problemœand the information gained through research a stude nt will be able to develop a better range ofœoptions as well as a more c onsidered final outcome.

3. Encouragement of student collaboration. T he use of groups is a basic principle of PBLœmethodology. The reason fo r the reliance on groups is to develop collaborative working skills inœt he students. In the early stages of the process of problem solving in g roups, brainstorming is vital. œThis is far more effective in a group en vironment than when done individually. The major reasonœfor this increa se in effectiveness is that there is a reduced level of fear of failure i n the groupœ(Killen, 1992,72).

The ability to work collaboratively with other students in the organising and planning of theœprocedure for solv ing a problem is vital for students who are to be involved in technology in theœfuture. The PBL process encourages this, as Feletti (1993,184) d escribes:

As a group the students will identify topics or issues w hich later become the focus of their independent studies. The group may subdivide the list, work individu ally or in small teams,œand later share their new information. As a par t of the group process, students may try toœexplain new ideas or reason t ogether how mechanisms work or systems interact. Throughœsuch activities students come to value teamwork, learn to make and keep commitments and œto realise that collaboration invariably leads to cooperation.

These skills and attitudes will be increasingly essential to the practising technology educator andœthe participants in technology activ ities.

4. Reflection on the process as well as the product. This four th aspect of the PBL methodologyœthat provides a valuable experience fo r technology educators is the emphasis on reflection. Theœability to ev aluate the effectiveness of the outcome, and the process followed in ach ieving thatœoutcome, has long been recognised as an important part of th e design process. The PBLœmethodology places an emphasis on reflection a s a part of the process, as well as the outcomeœachieved by that process . Another important aspect of this reflective process is that it also i ncludesœreflection on the learning experience that has

taken place while participating in the project. Felettiœ(1993,148) describes this reflec tive process thus:

This is a professional skill which requires each student to think about his or her learningœexperience as a whole. At a metacognitive level they can review what path theœlearningtook, whether this was according to plan and, if there were efficiencies in skills,œr esources or time, then what needed to be identified and overcome. In ot her words,œstudents and teacher can reflect on what might be done next t ime and what has changedœin them (individually or as a group).

The ability to participate in reflection wholistically is very impor tant for a technologist but theœability to reflect on the learning (pers onal change) that has taken place as a result of the process isœa very i mportant skill for an educator to have.

The PBL Project

The PBL methodology has the potential to be a most valuable means of teaching technology at all levels. At the University of Newcastle the Department of Applied Sci ence and Technology hasœdeveloped a subject based on the PBL methodology.

The subject was offered to the fourth year BEd Design and Technology s tudents for the first timeœin 1994. The subject introduced students to t he context of solar energy applications. Studentsœwere informed about t he PBL methodology at the beginning of the semester to ensure that theyœu nderstand the process and what experiences they are likely to confront d uring the project. œStudents selected their own group members, on lectur ers advice as to the criteria to follow. Theœstudents

have been expose d to a wide range of information and media about solar energy and itsœcu rrent applications.

The general problem in the context of solar energy a pplications has been presented to students,œthen students specify the co ntext and the problem as a part of the process of understanding bothœthe problem and the technology, based on group analytic research. Some of t he other features ofœthe project are:

1. Students work in groups of fou r. This group size allowed for high levels of individualœinvolvement but also provided experiences in the function and organisation of group w ork.

2. Student groups undertook preliminary research in the field of s olar energy application, materialsœprovided by the lecturers (eg. videos) initiated and supplemented student research.

3. Student groups identi fied a potential area of interest in solar energy application and undert ook in-depth research into this application in order to develop a design o pportunity.

4. Student groups organised their approach to solving the problem.

5. Student groups undertook the development of a working proto type which fulfils the developed design brief.

6. Student groups docume nted research, the input of individual group members, and prototypeœdesi gn and development.

7. Students evaluated their group's prototype as we ll as the process used to achieve the outcome.œThe students learning exp erience while participating in the project was also be evaluated.

The diagram in Figure 3 has been used to illustrate to students involved in t his project some of theœprocesses and expectations of the course. The ' INPUTS' represent the ideas generated from theœinitial individual resear ch. As these inputs are critically examined, the goal is to determine t he mostœsatisfactory solution to the problem, and this will be the input that continues through the funnel toœbecome the solution. In the conte xt of technology, the solution is generally a system or product.

The na rrowing funnel shape represents the increasingly specific and in depth r esearch that isœrequired as the group moves from broad superficial resea rch to problem solution.ÃThe numbers represent specific phases of activi ty.

The initial phase (1) is the presentation of the problem to the ind ividuals in the class, the resultingœwide ranging individual research th at is expected to help clarify and define the problem, and theœexposure t o lecturer prepared introductory material.

The groups are formed at (2) . It is hypothesized that initial individual research facilitates effect iveœgroup formation by providing a basis for complementary individuals w ithin groups. As the groupsœare formed, the research becomes immediately broadened, in the movement from individualœresearch to group directed r esearch. Then the group research becomes more specific and in greaterœd epth as the problem is clarified and

specified.

At about (3), the group should identify a solution to the
problem. Specific in-depth research, œorganized by the group, is
begun to be applied in solution construction .

The group solves the problem and presents the solution in (4).

The e valuation stage of (5) attempts to answer the question of
how well the p roblem has beenœsolved, and to evaluate the
learning process and efficac y of the group.

This project was run over two semesters in 1994. The a bove
features provide an overview of howœa variety of PBL methodology
wa s implemented into technology teacher education in this
project,œallowing an evaluation of the effectiveness of the methodol
ogy for wider application intoœtechnology education in general.

The gro ups selected a variety of solar powered applications to
develop, includi ng a wheel chair liftœto be installed at the new
koala enclosure at Blac kbutt reserve in Newcastle, an
illuminated suit forœbike riders, an aut omatic greenhouse
venting system, a hydroponics system and a swimming po olœskimmer
to collect leaves etc from the surface of a pool.

Evaluation

The projects that were developed by the students were all satisf
actory to excellent. The majority of the physical project
development work was completed in the last fe w weeks of the
course. Itœwas felt that if this development phase could have
begun earlier the results would have all beenœexcellent. There
w as some initial discomfort felt by both students and lecturers
with the p rocess;œstudents felt the need for specific direction
in the context of a situation in which they had to defineœand
address a problem, and it i s always a temptation for lecturers
to give the solution to a problemœra ther than guiding the
students to find an appropriate solution for thems elves.

An evaluation was conducted at the conclusion of the course, con
sisting of eighteen items to whichœstudents responded on a 5
point liker t scale from 'not at all' to 'completely', and two
open endedœitems. Th e data collected was analysed for
differences between student groups, an d differencesœbetween the
themes into which the items were grouped.

One group was composed of all female members. The total mean
for this grou p was significantlyœhigher ($F_{1,3} = 6.0$, $p<0.05$)
than other groups.   T his overall positive reaction could also
relate to the generally higher means from the female group with
regard to how w ell the group functioned. œ In other words,
because the group perceived t hemselves to function well, the

general attitude aboutœthe project was p ositive.

It was interesting to note that the rank order of groups based on the final assessment grade was theœsame order if the groups were ran ked according to total group means on all evaluation items. apartœfrom t he first two groups being reversed. A high total group mean is an indi cator of a general œpositive attitude toward the project. So those grou ps with the most positive attitudes scored theœhighest grades.

The evaluation items were grouped around six themes:

A open endedness of the project
B satisfaction of learning needs
C learner centred approach
D group work
E cognitive skill development
F researching new knowledge

ANOVA tests for the zero mean difference between themes resulted in the following:

Difference between B and D: $F_{1,4} = 12.62$, $p<0.025$ (B<D)
Difference between B and E: $F_{1,4} = 12.13$, $p\sim0.025$ (B<E)
Difference between C and F: $F_{1,4} = 8.51$, $p<0.05$ (C>F)

A possible interpretation of the results for B (satisfaction of lear ning needs) and D (group work)œis that students saw the group work exper ience as enjoyable and valuable, but not in the contextœof satisfying th eir learning needs. The B (satisfaction of learning needs) and E (cogni tive skill development) analysis could indicate that students appreciated the ac quisition of cognitive skillsœgained from the project, but didn't see th is as satisfying their learning needs.

These explanations are plausible given the history of these student's experiences of mainly didacticœand teacher centred instructional methods with an emphasis on individual ma nipulative skills ratherœthan cognitive and cooperative skill developmen t. Therefore, while they see group work andœcognitive skill development as enjoyable and profitable, they do not relate them to as a means ofœl earning. Stated another way, their experience with a variety of teachin g learning styles has beenœlimited, and therefore they were prevented f rom recognizing that alternative styles could also satisfyœtheir learnin g needs.

The analysis of C (learner centred approach) and F (researchin g new knowledge) could beœinterpreted as indicating that students apprec iate the learner centred approach, but do not realizeœthat this implies t he necessity of individually researching new knowledge.

These interp retations are reinforced by the negative responses to the item 'How oft en would youœuse a similar methodology in your teaching?' (third lowest m ean of all the items). The implicationœhere is that students did not se e problem based learning as a valuable method, despite appreciatingœsome of its elements, and could not see its relevance to teaching and learn ing.

The open ended items in the evaluation solicited general positive and negative comments. Theœmost common positive comments related to th e opportunity to develop a technology that was newœto students, and the a dvantages of working in groups where members have complementary skills. œT he most common negative comments related to the difficulty of motivating all group membersœequally, and the need for more clearly defined expec tations.

As a result of this project and evaluation, future applicati ons of problem based learningœmethodologies in technology should conside r the following points:

1. Carefully select group members to ensure complementary skills.

2. Develop a monitoring\reporting mechanism to keep groups focussed and progressive.

3. Establish deadlines for the completion of stages.

4. Improve the assessment mechanism that discriminates m ore fully among individual groupœmembers at stages throughout the course .

5. Comparatively evaluate performance and responses of a class that h as a background in studentœcentred strategies.

References

Australian Education Council. (1992). Interim Statement of Technology for Australian Schools. Melbourne: Curriculum Corporation.

Barrows, H. and Tamblyn, R. (1980). Problem Based Learning: an approach to medical education. New York: Springer

Barrows, H. (1986). 'A taxonomy of Problem Based methods', Medical Education. 20, 481-486.

Boud, D. and Feletti, G. (1991). The challenge of problem based learning. London: Kogan Page.

Carrick, (1989). The Carrick Report on Secondary Education. Sydney: NSW Government Printer.

Eckert, P. (1991). 'Preparing for the 21st Century by Collaboratively Learning for a more Productive School', Primary Focus. March, 9 -12.

Feletti, G. (1993). 'Inquiry based and problem based learning: how similar are these approaches to nursing and medical education'. Higher E ducation Research and Development. 12,2,143-156.

Kennedy, T. and O'Kelly, C. (1991). All in Cooperative Education. Carlton: Curriculum Organization.

Killen, R. (1992). Teaching Strategies for Design and Technology. The University of Newcastle D&T Development Project, Newcastle.

New South Wales Department of Education. (1988). Technology Education: Discussion Paper. Sydney: NSW Government Printer.

Addresses for Correspondence:

Anthony Williams
Applied Science and Technology
University of Newcastle
NSW 2308 Australia
Ph: +61 49 21 5865
Fax: +61 49 21 6990
asapw@cc.newcastle.edu.au

Dr P John Williams
Applied Science and Technology
University of Newcastle
NSW 2308 Australia
Ph: +61 49 21 6623
Fax: +61 49 21 6990
aspjw@cc.newcastle.edu.au

Ken Sutton
Applied Science and Technology
University of Newcastle
NSW 2308 Australia
Ph: +61 49 21
Fax: +61 49 6990