A PROBLEM-PROJECT BASED LEARNING (PPBL) APPLICATION TO THE TEACHING OF MATHEMATICS AND CHEMISTRY IN SECONDARY SCHOOLS AND TERTIARY EDUCATION

J .O. Fatokun
Department of Mathematical Sciences,
Anchor University, Lagos
NIGERIA
jfatokun@aul.edu.ng

K.V.F. Fatokun
Department of STM Education
Nasarawa State University, P.M.B.1022, Keffi
NIGERIA
victfatokun@yahoo.com

ABSTRACT

In this paper, we employed the concept of Problem Project -Based learning as a tool for learning Mathematics and Chemistry and in fact all Sciences from the viewpoint of using life situations or simulated scenario. Action research design was adopted through the use of case studies and the methodology involves some level of brain storming, after which active learning took place and knowledge gained by students either way through a collaborative learning situation became personalized within the group. Observation was made during the sessions and information gathered from participants through their response to interview. Three cases were discussed involving PPBL namely: Graphical interpretation of experimental readings in a Chemistry/Science laboratory as it enhances or makes use of basic mathematical knowledge, calculus in Science and lastly, the integration of curricular for Mathematics and the basic sciences at higher secondary and lower university levels. This findings from this study underscore the need for integration of the curricular of some basic concepts in Mathematics and the Sciences in general from the school level, thus it makes it easier for students in the tertiary educational level to learn higher and applicable concepts.

Keywords: Problem Project-based learning, Active-learning, Collaborative learning, Calculus.

INTRODUCTION

Problem Project -Based Learning (PPBL) has been applied for many decades in different fields of education in many countries. The first and best-known applications of PPBL are in the study of medicine during the1960s (Barrows 1985; Barrows 1996). Since then PPBL has spread worldwide to other disciplines in higher education such as architecture, economics, engineering, mathematics and law. Problem Project-Based learning has often been understood only as a method of learning. What distinguish PPBL as a teaching technique, as an educational strategy, or even as a philosophy are the changes in the whole learning environment that the approach requires. Defining PPBL as an educational philosophy means holistically considering a number of elements: the organizational context; curriculum content and design; and the teaching and learning approach, including the method of assessment and evaluation.

Although Problem Project -Based learning has been investigated in the context of education, the theoretical basis of PPBL is closely connected to learning in the work place. PPBL runs the same risks as any other progressive pedagogical idea: the baby might be thrown out with the bath water. PPBL can fail, for instance, because of mechanical application, or because no

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changes have been made on the curriculum level or because the assessment and evaluation system has not been developed in response to the new ideas about learning. In this article we examine the basis of PPBL knowledge and the prerequisites for the development of curricula and for the assessment of problem-based learning.

LITERATURE REVIEW

The basic premise of Problem Project -Based learning (PPBL) is that learning starts from dealing with problems that arise from professional practice. Traditionally, education has been organized according to the logic of separate disciplines and subjects. However, because professional practice and individual learning processes do not follow such divisions, this has led to a widening gap between education and professional practice in the work place (Boud 1985; Boud & Feletti, 1991; Poikela, & Poikela, 1997; Poikela, 2003). PPBL gathers and integrates many elements regarded as essential in effective, high quality learning, such as self-directed or autonomous learning, critical and reflective thinking skills, and the integration of disciplines.

In epistemological discussion, knowledge is usually divided into theory and practice. Theory is understood as propositional knowledge (knowing-what), and practice as procedural understanding (knowing-how). In a broader sense the relationship between knowledge (what) and knowing (how) can be understood as a debate between Cartesian finite and Heideggerian changing knowledge. The former represents the modern idea of permanent knowledge and the latter the post-modern way of apprehending knowledge as changing and dependent on the context of the activity rather than on facts or truth. In PPBL knowledge is seen as being more closely aligned to the post-modern than the modern view of epistemology (Cowdroy 1994).

Skill in metacognition is also essential for successful learning in PPBL environments. However, this skill may not be enough in engineering due to the nature of the knowledge domain. In PPBL the order in which topics are learnt is partly defined by the students themselves, hence some topics may be overlooked. Perrenet, Bouhuijs & Smits, (2000) describe the medical knowledge domain as having a "rather encyclopedic structure, so the order in which various concepts are encountered is not prescribed and further learning will hardly be affected by missing a topic" (in other words, if a topic is missed now, it can be filled in later). By contrast, mathematics, physics, chemistry and much of engineering have a hierarchical knowledge structure. Many topics must be learnt in a certain order, because missing essential parts will result in failure to learn later concepts. This problem will be hard for a student to correct; no matter how good their meta cognitive skills are, because they probably cannot fully compensate for missed topics as a result of using a PPBL method.

The problem-based curriculum should be organized as a student-centered learning environment. In concrete terms, this means knowledge acquisition from books in the library and gathering information from the internet, the media and from professional experts in working life. It means that lessons and exercises in school are no longer causes of learning, but resources for learning. Traditional curricula are taught and therefore also learnt, in a fragmented nature (Bialek & Botstein, 2004). Research shows that learners and students view Mathematics and Science as completely separate entities without realizing the links that exist between the curricula. This phenomenon has implications for teaching and learning in higher education as well as in schools (Hannan, 2000). Experience in teaching Mathematics in the University also show a highly skewed percentage failure rate in Elementary Mathematics of fresh students who major in other Sciences Atuahene & Russell, (2016). Traditional curricula are facing pressure to become more integrated and interrelate since a blend of knowledge is required for lifelong and meaningful learning. Lifelong learning in general and demand for continuous development of skills, knowledge and attitudes needed in working life in particular, have resulted in a call for new ways to organize learning Finucane, & Prideaux (1998). The knowledge gained in education becomes quickly outdated and lose its value for working life. Working life requires new kinds of competencies including independent knowledge acquisition and application, problem solving, co-operative and multi-dimensional professional skills and abilities for continuing learning. Problem Project -Based learning has been one of the approaches to bridge the gap between work and education. PPBL is an educational approach that has been adopted in various educational institutions around the world. However, some people consider that PPBL is not adequate for mathematics, and other abstract sciences, since it does not guarantee absolute accuracy and promotes know-how more than what-and-why knowledge for abstract notions.

Basic Consideration For Constructing PPBL In Mathematic And Chemistry

We presented in Fatokun J.O. and Fatokun K.V. F. (2013), that in order to build a PBL, we must first define precisely the main aims of the course. Here we concentrate our efforts not in terms of contents, but in terms of competencies, and how the quest for personal knowledge in Mathematics affects or interrelates with the quest for knowledge in Chemistry. So what are the abilities (the qualities) we want our students to develop? In like manner, for a Problem Project Based approach, a definite problem is identified and the following steps also applied as requirements for Mathematics, Chemistry and in fact most scientific subjects.

- Identifying some specific application areas for basic concepts.
- Personalizing knowledge.
- Capture the sense and need for rigor, in both written and oral expression
- Grasp the need for abstraction and use it appropriately
- Prove, generalize, criticize results
- Model different situations by using the appropriate mathematical tools
- Interpret and assess results.

Of course we also need to develop some specific contents (such as the notions of derivative, of linear mapping, matrix, matrix computation in Mathematics and Chemical equations, Graph plotting in simple chemistry experiments, and description of relationship between pressure, temperature and volume as in Boyles law….).

To implement PPBL in Mathematics and Chemistry, we really want the students to acquire a new notion and not to limit their work to the “how to use it”, which is the quite natural trend for most students. Most students are interested in corner-cutting and escaping with high scores in classroom assessment. This necessitates the need to be more directive on Mathematics problems than for PPBL in other subjects. Thus it is discovered that giving the students a key-word to be properly studied and understood by each student may be a good way to guide the students without cutting initiatives.

We claim that most of what is known for building a PPBL in applied subjects is valid for abstract ones (and particularly in mathematics and chemistry). However we must be more cautious so that the time spent by the student is essentially spent in mathematics (including oral and written expression), not in the applied domain (such as the

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production of an object). Quite often the corresponding work of the concrete object is, for math problems, computer results and for chemistry, some empirical lab readings.

The Principles Of Project-Based Learning Are As Follows

- The principle of inter--disciplinarily: Project-based learning is based on inter-disciplinarily, that is, it combines two or more academic disciplines (subjects) into one activity (project).
- The principle of active learning: Learning is based on the personal experience of learners.
- The principle of practicality: The theme of the project is closely related to practical problems taken from the learners' life.
- The principle of personal development: The teacher (facilitator) in all situations considers learners' needs and interests.
- The principle of self-regulating learning: Learners actively participatein formulating their own learning process.
- The principle of responsible citizenship: Learners need to be educated to actively work for their own community and be responsible for community affairs.
- The principle of gradualness: First the techniques of cooperative learning need to be implemented, then, in the second phase, the projects themselves can be introduced.
- The principle of regularity: Learners actively participate in all phases of project work from setting the goals through project activities to evaluation.

The operational phases of motivation are inseparable from one another. They are parts of a system of phases, functions, and components, thus motivation comprises implicit (internal) and explicit (external) levels.

Table 1. Introduction of Motivational System (Based on József Nagy, 2010. 261.)

The phases and functions of motivation	**Tools (components)**	
	Implicit	**Explicit**
Urge for assessment and decision making	motivator	Attention
Decision making	Motive	Value
Signalling interests	emotion	Goal
Urge for action	activation	willingness

The Difference Between Problem-Based And Project –Based Learning

The difference between problem-based learning and project-based learning is that students who complete problem-based learning often share the outcomes and jointly set the learning goals and outcomes with the teacher. On the other hand, project-based learning is an approach where the goals are set. It is also quite structured in the way that the teaching occurs.

Project-based learning is often multidisciplinary and longer, whereas Problem based learning is more likely to be a single subject and shorter. Generally, project-based learning follows general steps while problem-based learning provides specific steps. Importantly, project-based learning often involves authentic tasks that solve real-world problems while problem-based learning uses scenarios and cases that are perhaps less related to real life (Larmer, 2014).

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METHODOLOGY

In this work the methodology employed was to blend both approaches; Project-based learning and Problem based learning to achieve a better result.

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Case One: Graphical Interpretation Of Data

Secondary school (SS1) students were given short PPBL problems in the Mathematics class that integrated functions and graphs that were to be dealt with later in the Science class. These problems required students to draw graphs from data obtained from simplistic Chemistry laboratory experiments. The knowledge that was acquired from these problems were then linked to the specific curriculum content, addressed in the curriculum such as, graphs in gas behaviour that describes the relationship between pressure, temperature and volume (Boyles law). This approach was an attempt to assist learners with linking graphs in the Mathematics class to graphs in the Science class. This was an attempt to discourage learners from rote learning graphs in Science such as the graph of pressure versus temperature ($p = kT$) when it represents the mathematical form of a straight line ($y = mx+c$, where $c = 0$). Thus all the properties of a straight line (e.g. gradient, intercepts, directly or indirectly proportional) can be applied to this specific function. A similar example is the graph of pressure versus volume ($p = k/V$), which is the mathematical form of a hyperbola ($y = k/x$).

Case Two: Calculus In Science

A PPBL problem that was initiated in the Science class on the issue of providing alternative energy for a Science Laboratory: This problem would naturally lead to the issue of electricity. The tutorial classes for the 200 level (undergraduate group) here starts with discussions concerning the definitions of energy, power and work units of power. Solutions to this leads to applied Mathematics topics such as the applications of calculus through the use of rate of change of electrical energy in a household, rather than using the traditional method of using rate of change of displacement (speed) when introducing Calculus. The topic was further explored when learners had to plot a graph of electricity usage versus time, as well as interpret the graphical representation. This eventually led to brainstorming on integrating their knowledge on how to generate power for use in the science laboratory using all known theories. The outcome of this exercise is that the students would appreciate this integration of knowledge gained by themselves during the PPBL tutorial sessions.

Two examples were considered above to illustrate the need for integration of curricular for both Mathematics and Science (Chemistry). The first is applicable at the School curricula while the second addresses the University curricula.

Case Three: Integration Of Curricular

Chemical kinetics, thermodynamics and some chemical concepts cannot be taught or understood by learners efficiently without the basic knowledge of some fundamental mathematical concepts like calculus. Ascertain the rate of reaction in chemical processes during laboratory experiment and industrial operation is dependent on the knowledge of Calculus. Hence, there is need for transfer of knowledge and linkage of isolated ideas to existing knowledge structure through connecting related cognitive entities either mathematical or chemical and exploring them both in abstraction and realities.

RESULTS

Selected Students' View Of PPBL In Mathematics And Sciences

Most research on the influence of PPBL on Mathematics and Science students has been qualitative. In this write up, reactions collected show that students quickly identify the skills and personal development benefits of PPBL and its ability to model a real working environment:

> 'it's better in a group…with everyone's input…you can bounce ideas off each other…and others' ideas might be better. In industry you work in teams'
>
> 'better equipped for the future. In the future we'll know (when confronted with real problems) we've done something similar. It gives us group working skills'.

Some appreciation of the differences in approaches to learning between lectures and PPBL was also immediately obvious to the students:

> '[With PPBL] there's a lot more discussion about what's happening'.
>
> 'To learn the computational method at the same time as the problem is helpful.'
>
> 'it helped us to realise – we can do it'.
>
> 'practical learning… it really helped me to understand and apply the theory…I understand a lot more'

Other benefits were only realized by students in hindsight. These quotes are simulated from students who had participated in four two-week PPBL problems during their first and second years but who were interviewed during their third year project;

'we felt we needed preparation for PPBL but, actually, PPBL was a preparation for now'

> 'you have to learn it for yourself, not by preaching…you have to have the experience before you can see how good it is'

'[it was] excellent learning in a different style'

Some Facilitators View About PPBL Methods On Junior Secondary School Students

We have been running a large scale project based learning unit with our basic 7 students this term where they work in teams of 4 (mixed gender) to design and develop a video game to solve a water based issue. They met for 6 sessions a week together and negotiate their ideas, plan and then eventually coded it. Most games consisted of 2-3 levels that incorporated the learning from Science, Math, English, Geography and ICT. They created a game design document and had 7 weeks in total, after which they reflected and presented their learning at a public exposition. Their interactive digital games were properly designed. We engaged them initially with team building making activities and considering the hours they put in (almost 30 hours) with students outside their friendship groups, and that they were not traditionally 'assessed' all teams remained engaged to submit their games in the last week. Their intrinsic motivation, perseverance in the face of coding challenges and meta-cognition was inspiring. More challenging however has been persuasion from some of our teaching staff that game-based learning has real educational value, the traditional view that silo, subject-based learning of the 20th century is the only true learning experience is hard to shake, despite the growing evidence to the contrary.

The findings of this study show that PPBL in Mathematics and Chemistry is a means of integrating basic knowledge acquired from both subjects in order to proffer solutions to a well posed problem. The traditional way of formulating curriculum in an isolated manner can then be replaced with an integrated approach as seen in this work.

We want to emphasize here that there is no single model for a good problem, and various approaches are possible for deriving a Mathematics or Chemistry problem suitable for a PPBL setting. It is however necessary to complement PPBL work by other ways to do mathematics, such as usual exercises, numerical experimentation (also possible, of course, within PPBL), and to check that students do not share the work, especially that they grasped the generality of the studied abstract notions.

We also want to emphasize the importance of analysing a problem from different angles (context, information given, task, obstacle…).

In order to keep a high student involvement and motivation, we have to make sure that the sequence of problems allows for varied situations, and so encouraging discussions among the students. Of course, an a posteriori analysis of the sequence of problems is necessary to check that all objectives of the course (in terms of student competencies) are adequately covered. More important than learning Science and Mathematics, students need to learn to work in a community, thereby taking on social responsibilities.

DISCUSSION

Although students do work in groups, they also become more independent because they are receiving little instruction from the teacher. With Project-Based Learning students also learn skills that are essential in higher education. The students learn more than just finding answers, PPBL allows them to expand their minds and think beyond what they normally would. This finding is consistent with Larmer, (2014) assertions that students have to find answers to questions and combine them using critically thinking skills to come up with answers.

The most significant contributions of PPBL have been in schools located in poverty stricken areas; when students take responsibility, or ownership, for their learning, their self-esteem soars. It also helps to create better work habits and attitudes toward learning. In standardized tests, languishing schools have been able to raise their testing grades to a full level by implementing PPBL.

The outcome of this study reveals that adopting PPBL will bridge the gap that exist between acquisition of educational knowledge in school and actual competency in demonstrating such skills at work place when such knowledge is required. This is in line with Poikela, (2003) who earlier expressed that a wide gap exists between education and professional practice in the work place.

CONCLUSION

Finally we claim that it is completely possible to construct problems in mathematics and relate such to knowledge gained in Chemistry and vice-versa. There is need for adoption of PPBL to simplify instruction, thus making learning practical, interesting and applicable in solving real life problems both in school environment and workplace.

REFERENCES

Albanese, M. (2000) Problem based learning: Why curricula are likely to show little effect on knowledge and clinical skills. *Medical Education. 34, 729– 738.*

Atuahene, T. & Russell, T. A. (2016) Mathematics readiness of first year University students. *Journal of Developmental Education* (39), 12- 32.

Baker, C. M. (2000) Problem based learning for nursing: Integrating lessons from other disciplines with nursing experiences. *Journal of Professional Nursing, 16(5), 258- 266.*

Barrows, H. (1985) *How to design a problem-based curriculum for the preclinical years.* New York: Springer.

Barrows, H. (1996) Problem based learning in medicine and beyond: A brief overview. In L. Wilkerson & W. Gijselaers (Eds.). Bringing problem based learning to higher education: Theory and practice. San Francisco: Jossey Bass.

Bialek, W. & Botstein, D. (2004). Introductory Science and Mathematics Education *for 21 st Century Biologists, Science, 303, 788- 790.*

Boud, D. (1985) Problem Project -Based learning in perspective. In D. Boud (ed.) Problem Project -Based learning in education for the professions. Sydney: HERDSA, 13–19.

Boud, D. & Feletti, G. (1991) The Challenge of Problem-Based Learning. London: Kogan Page.

Cowdroy, R.M. (1994) Concepts, constructs and insights: the essence of problem-based learning. In S.E. Chen, R.M. Cowdroy, A.J. Kingsland & M.J. Ostwald (eds.) Reflections on Problem-Based Learning. Australian PPBL Network, Sydney.

Paulson, D.R. and Faust, J.L. Active Learning for the College Classroom. http://chemistry.calstatela.edu/Chem&BioChem/active/main.htm

Fatokun, J.O. & Fatokun K.V.F. (2013) Problem-Based Learning (PBL): An approach for integrating acquired knowledge in Mathematics and Chemistry for effective classroom delivery. *Educational Research and Review*, 8 (11), 663-667. DOI:10.5897/ERRO8.154 *http//www.academicjournals.org/ERR*

Finucane, P.M., Johnson, S. M & Prideaux, D. J. (1998) *Problem – based learning: It's rationale and efficacy. Medical Journal of Australia (MJA),168:445448. Retrieved March 8, 2005 from* http://www.mja.com.au

Hannan, A. (2000). *Changing Higher Education: Teaching, Learning and Institutional Cultures, A Discussion Paper for the Scottish Forum on Lifelong Learning, Education online,* http://www.leeds.ac.uk/educol/documents/00001855.htm

Naoum, K. B. & Wertz, V. (2002) PPBL *in mathematics: Why it works? (or* does *it work), Act es du congrès: PPBL 2002, A Pathway to Better Learning, Baltimore(USA).*

Naoum, K. B.; Rabut, C. & Wertz, V. (2008) *PPBL in Mathematics. Proceedings of the Problem Based Learning (PPBL 2008) Conference.*

Knoll, M. (1997) *The project method: Its vocational education origin and International development. Journal of Industrial Teacher Education, 34 (3),59- 80.*

Larmer, J. (2014) *Project-based learning vs. problem-based learning vs. X-BL.* Retrieved from http://www.edutopia.org/blog/pbl-vs-pbl-vs-xbl-john-larmer

Perrenet, J.C., Bouhuijs, P.A.J. & Smits, J.G.M. (2000) The suitability of problem-based learning for engineering education: Theory and Practice. Teaching in higher education,

ISSN 2056-5852

5 (3), 345-358.

Poikela, E. (2003) Context-based assessment. Refereed proceedings of the 3rd International Conference of Researching Work and Learning 25–27 July 2003. Tampere, Finland.

Poikela, E. & Poikela, S. (1997) Concepts of learning and the implementation of Problem-based learning. Zeitschrift für Hochschuldidaktik, Special Issue. Problem-based learning: theory, practice and research. Editors F. Eitel & W. Gijselaers. 21 (1), 8–22.

Poikela, E. & Poikela, S. (2001) Knowledge and Knowing in Problem-Based Learning. Refereed proceedings of 3rd Asia Pacific Conference on PPBL, Experience, Empowerment and Evidence. University of Newcastle, Australia.

Krivickas, R.V. (2005) Active Learning at Kaunas Unversity of Technology, Global *Journal of Engineering Education*, (9), 1(UICEE)

Savery, J. R. (2006) Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning, 1*(1). Retrieved from http://dx.doi.org/10.7771/1541-5015.1002

Vermunt, J. D. & Vermetten, Y. J. (2004). *Patterns in student learning: Relationships between learning strategies, conceptions of learning, and learning orientations. Educational Psychology Review, 16(4), 359 384.*