DISCERNING THE RUDIMENTS OF PBL DESIGN IN TUNE WITH REFLECTIVE HABITS FOR NURTURING MATHEMATICS PROFICIENCY

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Abstract

Mathematical thinking structures and creatively manipulates growing systems of thought. By integrating mathematics learning into real world application students can actively practice what they learn, make meaning out of their every day experience and think mathematically for tackling the problems successfully within today's information age. This study was mainly meant to develop a learning design based on Problem Based Learning as a strategy for promoting reflective learning practice among secondary pupils with special emphasis on mathematics learning and to establish the effectiveness of it in unfurling mathematics proficiency among secondary school pupils. The findings distilled from the study accentuated the efficacy of the select PBL design in enhancing academic performance as well as up hilling the levels of mathematics proficiency through reflective discourses and interventions.

Mathematics is one of humanity's great achievements of sophistication and beauty that epitomizes the vehicle for the formulation, organization and articulation of human thought. Mathematical thinking structures and creatively manipulates growing systems of thought. The goal of achieving higher mathematics competence for all students is unprecedented and it places vastly more ambitious performance demands on all aspects of educational system. A focused strategic program can evolve proficient problem solvers who can form mental representation of the problem, detects mathematical relationship, devise novel solution methods, hone their reasoning skills and improve conceptual understanding and willingness to put themselves against mathematical challenges. By integrating mathematics learning into real world application students can actively practice what they learn, make meaning out of their every day experience and think mathematically for tackling the problems successfully.

During the twentieth century the meaning of successful mathematics learning underwent several shifts in response to changes in both society and schooling. The research in cognitive psychology and mathematics education have led us to adopt a composite comprehensive view of successful mathematics learning. National research council (2001) have chosen mathematics proficiency to capture completely all aspects of expertise, competence, knowledge and facility in learning mathematics successfully. As a goal of instruction, mathematical proficiency provides a better way to think about mathematics learning. Mathematics proficiency implies expertise in handling mathematical ideas. Learners with mathematical proficiency understand basic concepts, are fluent in performing basic operations, exercise a repertoire of strategic knowledge, reason clearly and flexibly and maintain a positive outlook towards mathematics. As NRC (2001) suggested mathematics proficiency have five interwoven and interdependent strands namely conceptual understanding, procedural fluency, strategic competence, adaptive reasoning

and productive disposition which provides a framework for discussing the knowledge, skills, abilities and beliefs that constitute mathematical proficiency (NRC, 2001).

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Problem based learning

Problem based learning is a promising instructional method to help learners acquire the skills, competencies and knowledge to become effective planning practitioners. It describes techniques that make students take an active, task oriented and self directed approach to their own learning and provide students with insights into the research process. The facilitator, as a cognitive coach makes the learners active, collaborative and reflective problem solvers and thus they learn how to learn. In PBL there is emphasis on contextualization of the learning scenario, and learning through reflection is an important aspect of PBL. In problem based learning, the learner's primary role is that of a reflective and active problem solver; the facilitator must create an environment in which learners learn how to develop efficient and effective problem solving strategies and planning skills.

In a PBL environment, the locus of control of learning is a realistic problem on a subject area that promotes consideration of different perspectives and development of deeper knowledge that associated with an attitude that fosters inquiry and the ability to carry it out systematically. Real world problem scenarios and the selection of learning needs by learners themselves contribute to holding the student's interest in developing a deeper understanding of the content and increasing the retention of new information. PBL ends up orienting students towards meaning making over fact-collecting through contextualised problem sets and situations. Students are encouraged to take responsibility for their group and organize and direct the learning process with support from a facilitator. It can be used to enhance content knowledge and foster the development of communication, problem solving and self directed learning skill.

An inquiry based PBL approach to learning on the other hand, is an approach based upon a teaching philosophy in which the learning process itself is the goal, one in which individual's quest for knowledge and search for solutions are the learning objectives [Ronis, 2008]. PBL is a student centered instructional strategy in which students collaboratively solve problems and reflect on their experiences.Selected PBL problems should allow ample opportunities for students to demonstrate their growing and more mature abilities to conceptualize the problem by brainstorming, possible linkages to course content, experiment with new approaches in the light of reflection process and reassessing the experience in the light of its outcomes. Evidence indicate that peer support, active decision making

and planning help reduce the stress levels that these students often feel and can tackle PBL problems that are longer in duration, richer in content and more complex in problem solving challenges. Mathematics rests on the premise that learning is an active process in which learning mathematics is something pupils do, not something that is done to them. PBL process engage learners actively in self directed learning processes with a concerted group effort. This exploratory method of learning is so effective for mathematics education as it captures pupils' interest and forge significant learning links, amplify deeper understanding and expatiate retention of new information.

In the present study the investigators adopted the path ways of PBL proposed by Shepherd and Cosgriff (1998) namely **problem presentation, problem investigation, problem solution and problem evaluation.** As the learners proceed through these stages they become involved in scientific inquiry and exploration processes prompting reflective thinking and construction of knowledge necessary to solve the problem.

For developing the learning design the PBL design format was developed in accordance with KaAMS (kids as Air born scientist) model. KaAMS was a designed lesson model using the best theoretical and practical thinking about PBL. KaAMS model lesson proposed four stages namely **Frame, Inform, Explore and Try**. These successive phases are initiated with a lesson plan overview, which includes a lesson plan context, brief overviews of each part of the lesson, list of key concepts, background information, objective assessment and reflection suggestions, and cross-curricular extension ideas. The design ends with a list of support materials including additional background information and student worksheets.

Problem based learning design

A carefully constructed learning design provides evocative, intellectual, and practically grounded catalyst that stimulates learner's thinking; promotes professional learning and growth, and enhances progressive practices in mathematics education. The locus of such a design should centre on a learning environment that fosters the possibility for learners to engage in the process of knowledge production and reflection. In this study, the investigator prepared and tested the select Problem based learning design by synchronizing the coinciding phases of problem based learning proposed by shepherd and cosgriff (1998) and KaAMS model lesson strategy proposed by NASA. Activities incorporated through this learning design are collaboration and interactive bursts to get learners exited and involved in their learning. At the onset of the design the 'frame' phase of strategy is incorporated to the problem presentation in which a context for learning is established. The learners are exposed to the problem scenario of the new learning episode where they engaged in the sub tasks of goal setting; eliminate irrelevant information and gaining attention to the task goals. The problematic situation serves as the intellectual trigger, which evokes cognitive dissonance in the minds of learners. They deconstruct the problem scenario in to integral elements and conceptualize a mental model of the embedded issues. During 'inform' stage the learners begin to analyse the problem scenario to build hypotheses and launch investigation. Pupils organized their ideas and previous knowledge related to the problem and delineates key

issues within the problem. They reflect on strategies and resources to generate solutions strategies. The ‘explore’ stage of the design is learner directed in which they think creatively, explore the learning issues and integrate their new knowledge in to the problem that leads to the development of general principles, abstractions, and problem solving techniques. The learners are encouraged to reflect on the reasoning process, investigative methods, opinions and information that refines their understanding of the problem and problem solving process. In the final phase of the PBL design namely ‘try’ learners assess themselves their performance and apply the new knowledge in novel situations and go public to share what they have learned with regard to the learning process, the resources used, barriers and successes, the implementation efforts and recommendation for improving PBL process. The facilitator ensures that the learners take responsible role in the learning. By working productively with other group members and by looking at issues from a comprehensive perspective, the learners are actively engaged in a planning process similar to what they will encounter as professionals. The learners are required to determine the reliability and applicability of information they acquire during the investigative process and must design and commit to solutions. The facilitator is responsible for probing the learners’ knowledge providing cognitive guidance and feedback and assessing the PBL process together with the learners and should ensure that all action and learning is learner directed and learner motivated.

A synoptic imprint of the select Problem based learning design is portrayed in Figure 2

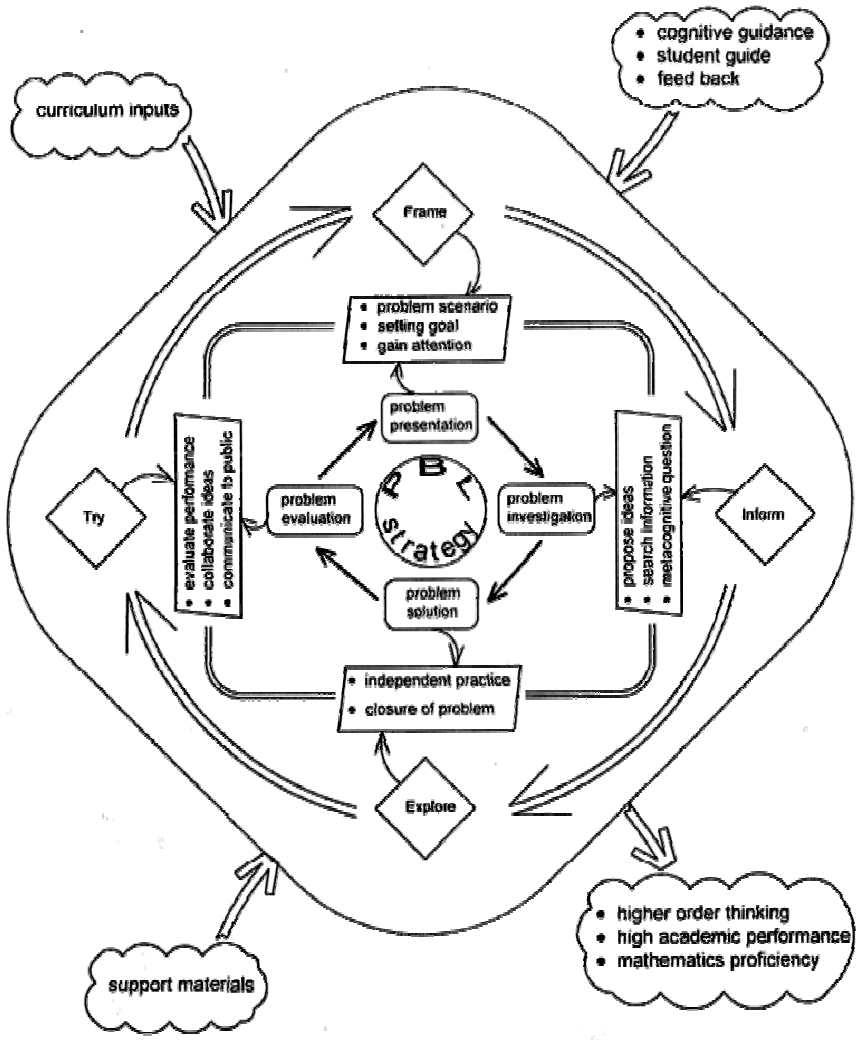

Figure 2. Synoptic Imprint of Problem Based Learning Design

Statement of the problem

This study was mainly meant to develop a learning design based on Problem Based Learning as a strategy for promoting reflective learning practice and to establish the effectiveness of the select design in unfurling mathematics proficiency among secondary school pupils

Objectives

- To test the effectiveness of Problem Based Learning design in improving the academic performance in mathematics of pupils at secondary school level.
- To explore the effect of Problem Based Learning design in augmenting the set levels of mathematics proficiency of pupils at secondary school level.

Hypotheses

- The select Problem Based Learning design is effective in improving the academic performance in mathematics of pupils at secondary school level.
- The select Problem Based Learning design is effective in augmenting the set levels of mathematics proficiency of pupils at secondary school level.

Methodology in brief

The present study attempted to empower the student folk at secondary level with mathematics proficiency by exposing them to Problem Based Learning design. For attaining the set objectives of the study both quantitative and qualitative methodology were adopted. The quasi-experimental design with pre test posttest non equivalent group design was employed for the quantitative segment and the analytic rubric for synchronized assessment in mathematics proficiency for the qualitative segment. The sample or participants of the study primarily consisted of 141 pupils at secondary school level.

Analytical supports of the study.

- Achievement test in Mathematics
- Analytic rubric for synchronized assessment of mathematics proficiency
- Lesson design based on Problem Based Learning design

Statistical procedures employed

T-test of significant difference between means, ANCOVA, Adjusted means

Analysis and interpretation

In order to find out the effectiveness of Problem Based Learning design with respect to achievement in mathematics of pupils the investigator analyzed the post test scores of the control group and experimental group who were exposed to Problem Based Learning design. To find out whether any significant difference exists between the experimental group and control group, the mean and standard deviation of the posttest scores of achievement were estimated. The critical ratios were found out based on the data presented in the Table 1.

Table 1 Test of Significance of the Mean Post test Scores of Achievement

Sl. No.	Sample	Control group			Experimental group			Critical Ratio	Level of significance %
		Mean	SD	No. of Pupils	Mean	SD	No. of Pupils		
1	Total	19.51	7.32	75	29.19	10.65	66	6.08	0.01
2	Urban	20.60	7.46	36	29.06	11.05	32	3.72	0.01
3	Rural	19.20	7.28	39	29.11	10.27	34	4.79	0.01

4	Male	19.6	6.88	37	29.33	10.52	30	4.47	0.01
5	Female	20.15	7.33	38	29.08	10.90	36	4.15	0.01

The obtained critical ratios for the total sample, locale wise and gender wise sub samples are significant as their level of significance is 0.01%. This indicates that significant difference exists between the mean scores of the post achievement test of experimental group and control group. The table values show that the higher mean scores are associated with the experimental group imply that experimental group shows better performance than the control group in their achievement for the total sample, locale wise and gender wise sub samples.

Single factor ANCOVA with pre-experimental status in achievement as covariate was employed to investigate the effectiveness of Problem based learning design in enhancing academic performance in mathematics over present activity oriented approach The details are given in Table 2.

Table 2. Summary of ANCOVA of Pre test and Post test Achievement Scores

Source	Type III sum of squares	df	Mean squares	F- value	Level of significance %
Model	50353.425 (a)	1	50353.425	246.355	0.01
Control post	50353.425	1	50353.425	246.425	0.01
Error	13285.575	65	204.393	204.393	
Total	63639.000	66			
a R = squared = 0.791 (Adjusted R squared = 0.788)					

The obtained F- ratio (246.355) is significant as the level of significance is 0.01%.

It can be inferred from the covariance analysis that after a linear adjustment was made for the effect of variation due to differences in the pre-experimental status in mathematics achievement as measured by the covariate, there is statistically significant difference exists between the experimental group and control group in the post test scores for the total sample. This means that the experimental group performed better than the control group in their post achievement test.

An additional analysis was done in order to determine which one of the two groups based on Problem based learning design cause difference from another in terms of the variation in the criterion mean. Adjusted means of achievement for the experimental group was calculated using regression equation for the total sample. The details are given in Table 3.

Table 3. Adjusted Mean of the Post test Scores of Experimental Group.

Sl. No.	Sample	Mean	Mean of experimental group	Adjusted mean of Experimental group
1	Total	19.69	29.19	30.18

The obtained adjusted means of experimental group for total sample is found greater than the corresponding means of control group. It can be inferred from the result that the experimental group is better than the control group with regard to the post achievement scores. Thus it is evident from the analysis that Problem based learning design enhances the achievement level in mathematics of secondary school pupils.

The investigator conducted a qualitative analysis to substantiate the findings drawn through the quantitative analysis of the data. A self-assessment analytic rubric of mathematics proficiency was developed, validated and employed for this purpose as it provides an explicit language for goal setting and personal mastery. The rubric was administered to the experimental group, which was treated, with Problem based learning design before and after the experimentation and the number of pupils fall under each of the select levels of performance for each criteria was estimated. The corresponding percentage of pupils and their averages were computed and is described in Table 4

Table 4. Percentage of Pupils under Novice, Basic, Proficient and Advanced Levels of Performance.

Levels of performance	Novice %		Basic %		Proficient %		Advanced %	
Criteria	Pre-test	Post test	Pre-test	Post test	Pre-test	Post- test	Pre test	Post test
Conceptual understanding	72	25	20	52	8	16	Nil	7
Procedural fluency	73	18	21	51	6	21	Nil	10
Strategic competence	72	19	22	53	5	20	1	8
Adaptive reasoning	70	21	25	49	5	24	Nil	6
Productive disposition	74	21	20	53	6	18	Nil	8
Average	72.2	20.8	21.6	51.6	6	19.8	0.2	7.8

Table 4 shows that the average percentage of pupils coming under Novice, Basic, Proficient and Advanced level of performance in mathematics proficiency before the experiment are 72.2%, 21.6%,6% and 0.2% respectively where as those after the experiment are 20.8%, 51.6%, 19.8% and7.8% respectively. It is also clear from Table 5.41 that the proportion of pupils coming under Novice, Basic, Proficient and Advanced levels in each strand of mathematics proficiency changed remarkably after the treatment of the select Problem based learning design. The percentage of pupils coming under Novice level in every strands of mathematics proficiency decreased considerably where as percentage of pupils coming under Basic, Proficient and Advanced levels increased after the experiment. This indicates that there is a noticeable increase in the percentage of pupils coming under Advanced, Proficient and Basic level of performance after the experimental treatment of Problem based learning design. The percentage of pupils coming under

Novice level of performance decreases after the treatment of Problem based learning design. This result point towards the conclusion that the Problem based learning design is effective in enhancing the level of performance of pupils from Novice level to Advanced level in mathematics proficiency.

Major Findings and Conclusions

1) Problem Based Learning design is effective in improving academic performance in mathematics of secondary school pupils.

2) Problem Based Learning design is effective in upbringing the set levels of mathematics proficiency.

Discussion of Result

The results of the study enunciated in this regard underpins the idea that an effective mode of capitalizing on the learning can be to enable the learners to progress in their conception of knowledge structure through the praxis of reflection. The ascendance in the performance unfurled by the experimental group who were treated with the PBL lesson designs may be due to the concomitant features attributed to the select design to enculture reflective dispositions towards learner's justifying and defending participation to provoke, mediate, capture and improve social and mathematical discourses .This observation is in accordance with the claim (Wu & Forester, 2003 as reported by Kumar and Natarajan,2007) that PBL elevates learning issues from being considered at the level of cognition to being validly considered at the level of meta cognition as well.

For articulating a qualitative dimension to predicate the preponderance of the select Problem based learning design, a self assessment rubric of mathematics proficiency was also employed to the select sample of pupils at the very outset of the experimental intervention as pretest. This analytic rubric is an academic citadel of the persuasive evidences of the intellectual moves and commitments to be enacted by a skillful mathematics learner arranged in a continuum of varied performance levels. The conscious immersion of the learners in to the aforesaid mental excursions of the set strands of mathematics proficiency might have embarked and oriented actions through analysis and holistic proposals of experiences. The subsequent exposure of PBL designs among the pupils at secondary level could have radiated an intellectual curiosity to speculate, hypothesize and emerge new pathways for provocative discoveries in the procedure resolutions of their learning agenda. The overarching primacy in the performance unfolded by the select experimental group of sample may be due to the higher cognitive structure and the intense programmic focus captivated through the phased execution of the PBL design process in every mathematical intervention. It gave the learners a chance to draw on their own experiential knowledge and allows them to reflect on the very process of their own thinking and meaning making of mathematical tasks.

The proemial phase of the design offered to present a host of challenges and issues around the academic development through the problem scenario. They were scaffolded for independent and interdependent research,

inquiry, hypotheses generation, discernment of credible sources and resources to derive new perspectives in setting goals. The second phase of the design awakened the learners with the problem heuristics such as working backwards, breaking up the problem into smaller segments and setting up sub goals. During the third phase the pupils were armed with innovative modes of executing mathematics learning tasks assumed. They worked with clarified thinking and discourses in a way that augments the analytic tasks at hand by interlinking the network of meaningful association of mathematics schemata. The last phase of the PBL design ingrafted the learners with an intellectual repository of enhanced cognitive and metacognitive capacities. Active engagement in the new learning event stimulated further learning and required research, elaboration, analysis, synthesis together with decisions and action plans. Thus PBL design tracked the movement of learners to strengthen the cognitive faculty to enhance comprehension, social skill development, content retention, student motivation and abilities to self direct and it engenders positive attitude towards life long learning.

The findings distilled from the readministration of the rubric also accentuated the efficacy of the select PBL design in uphilling the levels of mathematics proficiency through reflective discourses and interventions. The investigator could recognize that PBL design could act as a pivotal discursive site for developing invaluable life skills such as problem solving, independent thinking, self directed learning skills and metacognitive judgments and monitoring by setting rich environment for learning mathematics in participatory and investigative ways. It has offered opportunity for cognitive, psychological, emotional and ethical developments by which learners are attuned to the pursuit of excellence and edification.The above findings of the study accentuated that the stance of learning rooted in PBL pedagogy has affordances in metacognitive growth detriment to the progressive mechanism of rigorous mathematical thinking.

This trend is in agreement with the following findings.

Mergendoller, Maxwell and Bellisimo (2006) established that PBL was found to be more effective than traditional Lecture-discussion approaches in teaching macro economic theories in four California high school and arousing interest in the subject. A study among geography students taught with PBL approach revealed that they had gained more in depth knowledge and became more skilled in thinking critically and solving real life problems (Kwan and So, 2008).Visseb (2002) found that in a high school genetics class students taught with a PBL approach showed more confidence in learning than students given lecture based instruction.

Implications of the study

The present study emphasizes the inherent social nature of the Problem based learning design in all the learning endeavors, interchange of ideas and multiple perspective to enhance the learning process. Through mutual exploration, meaning making and feedback learners could germinate creative ideas for framing solution strategies and determine the legitimacy of the proposed strategies in this new learning paradigm that enforces

them to perform in a better way.This implicates the positive impact of incorporating pedagogic tools blended with PBL design elements into the curriculum development.

In Problem based learning design, the learners became active learners, and collaborative problem solvers who were very efficient to build strategic competence in solving non-routine problems. As the learning occurs in real life situations in Problem based learning strategy, learners could functionalize mathematical concepts easily, apply solution procedures fluently, determine adequacy of procedures fruitfully, monitor the progress of the strategies competently, generate multiple plans of solution paths if needed and tackle challenging mathematics tasks whole-heartedly. Thus, the learners are encouraged to play a more central role in their own learning process more rooted in reflective, discursive and collaborative ways of working with problem heuristics. This enhanced intellectual benchmarks and scintillating experiences provided by Problem based learning design capacitated the pupils to move towards the Basic, Proficient and Advanced levels of mathematics scholarship. Hence it is high to orient the educational practitioners at all levels to concientise the very urgency to design their pedagogical endeavors in tune with the punching hunches of PBL design.

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