Far East Journal of Mathematical Education
Volume 10, Number 2, 2013, Pages 207-213
Published Online: June 2013
Available online at http://pphmj.com/journals/fjme.htm
Published by Pushpa Publishing House, Allahabad, INDIA

LEARNING GEOMETRY FROM ARCHITECTURE

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Abstract

Problem-based learning model can help students to study oneself from the question even more. This research thinks Luce Chapel in Tunghai University as the model to incorporate geometric concepts. It comes to develop a teaching aid to excite students of different stages thinking the designed questions and to assist teaching.

1. Introduction

People acquire knowledge primarily through the experience of various sensations and actions. From the learning perspective, people learn through interactions with their environment and persistent knowledge is gradually learned from experience through senses and various actions. Therefore, teaching should combine social, scientific, and technological facts to assist students in conceptualizing their scientific concepts with learning activities that are designed to encourage them to discover and investigate nature, apply knowledge to various learning activities, and explain daily life problems. The ideal pedagogy is one that provides direct experience, namely object teaching. The conventional definition of object teaching is that teachers

Keywords and phrases: problem-based learning model, geometry, teaching aid, Luce Chapel.
Communicated by K. K. Azad
Received February 7, 2013

employ real objects to assist teaching delivery. These objects are effectively teaching aids that assist teachers in teaching and students.

Problem-based learning (PBL) method has been practiced broadly in the academic domain to facilitate self-learning when students are required to implement self-learning through questions. The core concepts of PBL are using professional knowledge, goal-setting, problem resolution, and evaluation of the results. PBL is applicable to various scenarios, although slight adjustments of the PBL process are necessary. Moreover, PBL has the following characteristics:

(1) Initiating learning with a real problem.

(2) Connection between the cognition and professional knowledge of the learners and the problems.

(3) Learning in small groups.

(4) A self-oriented learning model.

(5) Teachers or experts are considered helpers, not leaders.

The study uses Luce Chapel of Tunghai University as a teaching aid model to extend various geometric concepts by applying PBL, and develop related problems based on various student backgrounds in mathematical learning. They include the structure of 3-dimensional space comes by way of designing and counting the building blocks; lead students to calculate the surface area, volume, and pile up the building blocks to utilize arithmetic progression; let the high school students utilize elementary functions and conic sections, and, by the fact that the Chapel tiles levelly and smoothly, some advanced geometric concepts can be also introduced to university students.

2. PBL Literature Review

PBL can be defined from various perspectives. Barrows and Tamblyn [1] defined PBL as the process in which learners learn knowledge by understanding or solving specific problems. Other studies (e.g., Fogarty [7])

have considered PBL as a course model that focuses on real-world problems. Torp and Sage [14] considered PBL as experiential learning because it can be employed as a curriculum organizer and a teaching strategy. Schmidt [12] and Walton and Matthews [15] indicated that PBL is a learning method and can be used to explain the process of learning and teaching. Numerous studies believed that PBL was initially developed as a teaching method for training medical students to discuss and solve clinical medical problems; and a student-centered and real problem solving apprenticeship-style contextualized teaching method or strategy that anchors learning and teaching to the problem itself. (Boud and Feletti [3], Bridges and Hallinger [4], Delisle [5], Dods [6], Hoffman and Ritchie [9], Hmelo and Lin [8], Norman [10], Norman and Schmidt [11], Stepien et al. [13]). Barrows [2] also indicated that PBL is a flexible teaching method, the definition of which may differ in accordance with the teaching design and the skill of teachers. Briefly, one can conclude that PBL has the following characteristics:

(1) Using an ill-structured problem as the focus of organizing a curriculum and scenario of learning.

(2) Learners become stakeholders.

(3) Teacher as a trainer in cognition and meta-cognition.

(4) Encouraging group cooperation and learning.

(5) Multiple evaluation methods.

3. Connection between Luce Chapel in Tunghai University and Geometry in Mathematics

Luce Chapel is a significant building in Tunghai University and a landmark of Taichung City. The design of Luce Chapel is a mixture of traditional and innovative concepts. Taoism embraces the concept of "materialization from nothingness, and substantiation from nihility". In architecture, this concept is elaborated as being "columnless, beamless, and wallness" in the past and having "column, beam, and wall" in the present. The thin exterior structure of Luce Chapel expands on these concepts by

employing a novel concept of "column is also beam is also wall". Therefore, the appearance and architectural structure of Luce Chapel can serve as a teaching aid creation tool and a good teaching material that can be applied to the PBL system. Moreover, parts of its basic and advanced geometric concepts can be expressed using the teaching aid model.

Figure. Luce Chapel.

a. Elementary geometric concepts:

a-1. The concept of 3-dimensional space: The model of Luce Chapel will be designed by piling up the building blocks. Students will be asking to describe by looking at the outward appearance the solid structure of the model. It be a single (or combination of some) prismoid(s), depending on the students' observation.

a-2. The concept of symmetry: Introduce to students the concept of symmetry. Ask them to justify whether the Chapel is symmetric or not. (Can it be proved by counting the building blocks?)

a-3. The concept of elementary plane geometry: We will also make some different layouts of the model. By piecing together these layouts, students can learn how to get a solid figure.

b. For junior high school students:

b-1. Estimation of the surface area: Students can estimate the surface area by counting the area of outwards part of the building blocks. One can also introduce to them the concept of the error.

b-2. Estimation of volume: Building blocks of the model are different kinds of prismoids. Students will be ask to compute the volume of each kind of prismoid and then to estimate the volume of the Chapel.

b-3. The concept of sequence and series: In computing the number, the area of outward part and the volume of the building blocks of the model, students are ask to develop the computing methods by use of the concepts of an arithmetic progression or a geometric progression.

c. For senior high school students:

c-1. Conic sections: The two sides of the Chapel are in fact constructed by two hyperboloids. By projecting the hyperboloids to a plane, students are asked to find a suitable equation for the hyperbolic. By observing the model of the Chapel, they are also asked to know how to determine an equation of a hyperbolic from giving points.

c-2. The space vectors: The outward normal vector of each building block is unique. Students are asked to find the difference between the normal vectors in the model and those in the hyperboloids of the two sides of Luce Chapel.

c-3. Something about the Graph Coloring Problem: Students are asked to color the outward appearance of the building block model and the planar layouts. They have to find the smallest number of colors so that the neighboring regions have different colors.

d. Advanced geometric concepts:

d-1. Calculus: Students are asked to analyze the equation of the hyperbolic such as the monotonicity and concavity, and discuss the relationship between these properties and the structure of the Chapel.

d-2. Euclidean geometry: Students are asked to compute the dihedral angles of the Chapel and those between the building blocks of the model. Moreover, to inlay smoothly the building blocks without gaps, which mathematical theories do we need? Is it related to the Parallel Axiom?

d-3. Elementary differential geometry: Students are asked to realize the geometric properties of the hyperboloids in two sides of the Chapel. They include the tangent vectors, the normal vectors and the computation of the space curvature. Furthermore, the minimal distance problem in the Chapel can also be considered by finding the minimal geodesics in the hyperboloid.

4. Conclusion

This paper presented an idea that teachers may help students to integrate learned geometric concepts by investigating the structure of architecture. We took the Luce Chapel located in the campus of Tunghai University as an example and described which geometric concepts and problems we can involve in the structure of the building. It is recommended that future studies thoroughly examine the connection between the mathematical theories and the characteristics of a nearby or popular building by applying theories such as PBL and brainstorming. In addition, a teaching aid prototype should be developed through demonstration, assembling, envisioning, and analyzing of the teaching aid implementation at the scene to easily and specifically show the geometric concepts and enable the students to have a deeper understanding of these concepts. It should be further improved, completed, and promoted to effectively assist mathematical teaching at various stages.

Acknowledgement

This project is partially supported by Taiwan NSC grants (NSC 100-2511-S-029-001 and NSC 101-2511-S-029-002).

References

[1] H. S. Barrows and R. M. Tamblyn, Problem-based Learning: An Approach to Medical Education, Springer, New York, 1980.

[2] H. S. Barrows, A taxonomy of problem-based learning methods, Medical Education 20 (1986), 481-486.

[3] D. Boud and G. Feletti, Introduction, D. Boud and G. Feletti, eds., The Challenge of Problem Based Learning, St. Martin's Press, New York, 230, 1991.

[4] E. M. Bridges and P. Hallinger, Problem-based Learning for Administrators, ERIC Clearinghouse on Educational Measurement, University of Oregon, Eugene, OR, 1992.

[5] R. Delisle, ed., How to use problem-based learning in the classroom, Association for Supervision and Curriculum Development, Alexandria, VA, 1997.

[6] R. F. Dods, An action research study of the effectiveness of problem-based learning in promoting the acquisition and retention of knowledge, Journal for the Education of the Gifted 20(4) (1997), 423-437.

[7] R. Fogarty, Problem-based learning and other curriculum models for the multiple intelligence classroom, IRI/SkyLight Training and Publishing, Inc., Illinois, Arlington Heights, 1997.

[8] C. E. Hmelo and X. Lin, Becoming self-directed learners: Strategy development in problem-based learning, D. H. Evensen, and C. E. Hmelo, eds., Problem-based Learning: A Research Perspective on Learning Interactions, pp. 227-250, LEA, Mahwah, NJ, 2000.

[9] B. Hoffman and D. Ritchie, Using multimedia to overcome the problems with problem based learning, Instructional Science 25 (1997), 97-115.

[10] G. R. Norman, Problem solving skills, solving problems and problem-based learning, Medical Education 22 (1988), 279-286.

[11] G. R. Norman and H. G. Schmidt, The psychological basis of problem-based learning: a review of the evidence, Academic Medicine 67(9) (1992), 557-565.

[12] H. G. Schmidt, Foundations of problem-based learning: some explanatory notes, Medical Education 27(5) (1993), 422-432.

[13] W. J. Stepien, S. A. Gallagher and D. Workman, Problem-based learning for traditional and interdisciplinary classrooms, Journal for the Education of the Gifted 16(4) (1993), 338-357.

[14] L. Torp and S. Sage, Problems as possibilities: Problem-based learning for K-12 education, Association for Supervision and Curriculum Development, Alexandria, VA, 2002.

[15] H. J. Walton and M. B. Matthews, Essentials of problem-based learning, Medical Education 23 (1989), 542-558.