Unified Teaching Strategy of Air Chemistry in Engineering

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Abstract

Problem-Based Learning (PBL) is a new modern pedagogical teaching method that challenges students to learn creative thinking, shared responsibility, individual responsibility for learning, problem development, analysis of problems based on the curriculum dimension and real world issues. Availability of the multimedia in the classroom enables students and instructors the instant gratification of the content via the Internet and e-mails. PBL has been used to teach a graduate "Air Chemistry and Engineering" course at Lamar University. In this paper, we discuss a new innovative teaching strategy of Air Chemistry in Engineering. Students are encouraged to formulate and solve problems that provide exposure to the content that fits a unifying model of the subject materials as illustrated by the student developed relationship chart. The presentation will detail how this approach develops creative thinking based on encompassed concepts and detailed models.

Introduction

Engineering educators have long sought pedagogical practices that prepare students to think critically and analytically. Today, cyclic and spiral processes continue to develop, studied and applied. Problem/Product Based Learning is a cyclic process. The speed of these cycles have been dramatically enhanced by the evolution of the digital classroom and this is providing more opportunities for practicing and improving PBL. Problem-based learning (PBL) challenges students to "learn to learn", to find and use appropriate learning resources, to develop inclusive concepts and models, to produce solutions or products, to think critically and analytically and form the basis for life long learning by working cooperatively in groups. PBL is based on constructivism and as such is an open frame work that can be used to adopt or adapt other useful learning and teaching strategies. Several of these are basic and have proven quite useful as technology is being integrated into the classroom and the classroom learning strategies.

Technology integration into the classroom is occurring in numerous ways. This is in the forms of interactive web-pages, digital based presentations (power point, pdf documents), Internet linked classroom computers, smart boards, etc. From the students perspective this is facilitating their learning through enhanced learning objectives, accelerated access to content and altered learning processes. From the instructor's perspective, it is challenging past practices and opening new opportunities.

Universities are responding with studio classrooms, digital learning laboratories, distributed classrooms using remote access to virtual laboratories and other elaborate facilities. A common thread through all of the new settings is to capacity it allows to design, explore and verify concepts and models that unify and build students conceptual understanding provide the spring board of creativity. The new challenge of this evolving digital pedagogy and digitally aided learning approaches is to exploit the power of conceptualization and modeling in learning processes. To explore this, examination of cyclic learning models that use conceptualization as an essential element is warranted.

The PBL Classroom

Pedagogy in a digital world is an evolving new paradigm in learning and teaching. Technology enabled teaching and learning has a long history. From black boards to document cameras and smart boards, education has been marching forward at an ever-increasing pace. In the early 1990's Dr. Jack Gill and Dr. David Cocke envisioned the computer and video aided teaching (CAVAT) classroom and pedagogy. Unfortunately, the concepts had to await the arrival of digital technology that is becoming available today to be implement the level of digitally aided teaching and learning that Gill and Cocke envisioned. The Internet, along with the convergent technologies that can now be assembled is providing the basis for a rebirth of interest in reforming learning and teaching methodologies and evolving a new pedagogy that embraces enabling technology but retains the time proven principles that enhance learning. This is a non-trivial task and ranges over the entire K-Doctorate spectrum. We find ourselves as teachers having to learn digital technologies and their associated pedagogical advances and simultaneously continue to provide rewarding and workable learning experiences for the students. The authors have established the Gill Advanced Learning Institute, which houses the experimental Gill Advanced Learning Laboratory, GALL, a convergent technology pedagogy laboratory. Many of the concepts and evolving methodologies were put into practice by a CCLI-NSF Grant (9981152) in 2000[1]. That has been followed by another two NSF Grants (0435627 and 0533227) in 2004 and 2005, respectively, for exploring this enabling technology in Trilingual Education (English, Spanish and Signing) in teaching and learning science[2,3].

GALL is a test bed for merging technologies, establishing best practice digital pedagogy and discovering new learning and teaching technologies. The versatile classroom design optimized for problem based learning, group discovery and multiple-meeting based scenarios is observed in the diagram in Figure 1. This classroom-learning-laboratory consists of a square space filled with four group study tables. Each group table has six computers, a printer, a smart board, and a LCD mounted above the center of the room that is visible only to each group table. A movable instructor podium is located preferably in the center of the room. This location discourages conventional lecturing. It can however be moved to one side as shown in Figure 1. A large 42 inch back projection smart board is located opposite a drop screen. Both can be used for power point presentations. This arrangement can accommodate four six member PBL groups or more as needed. The four LCD's can be linked to show same information for presentation to all the PBL groups simultaneously.

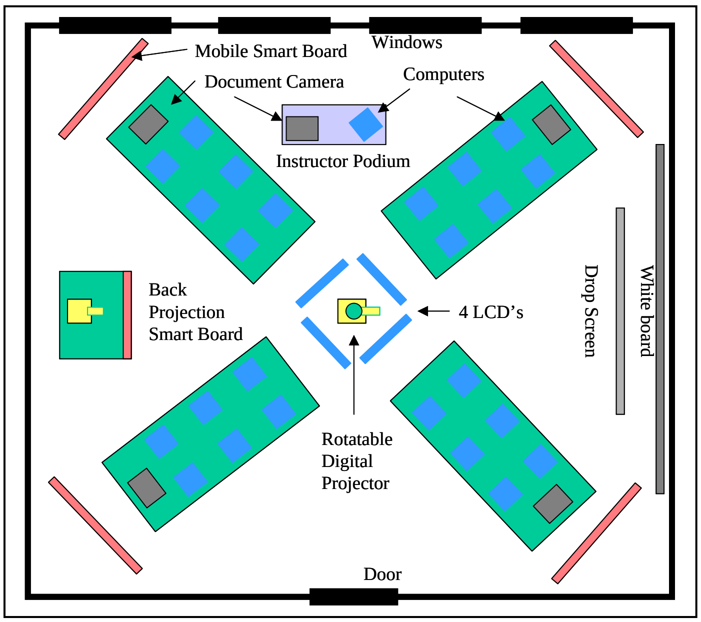

Figure 1. The convergent classroom used in PBL

Learning Cycles

Kolb's Learning Cycle is the prime example. Kolb's experiential learning theory is one of the major educational theories being used in both research and practice in higher education[4,5]. It is based on the four-stage learning cycle shown in Figure 2: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Learners can go through the cycle numerous times resulting in a spiral of cycles. Kolb[5] further suggests that students have preferential ways of learning and can be classified as divergers, using brainstorming and generation of ideas, assimilators, using inductive reasoning and creation of models, convergers - using hypothetical-deductive reasoning and accommodators – plans, experiments and immediate circumstances to learn. The Bloom taxonomy[6] provides the expected learning levels for the stages. It has six levels for the cognitive domain: knowledge, comprehension**,** application, analysis, **s**ynthesis and evaluation.

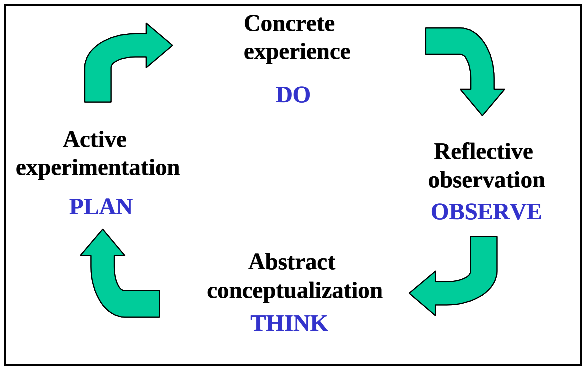

Figure 2. Kolb's learning styles (After Jenkins[7])

Conceptualization obviously plays a key role in the process of learning. Conceptualization involves using logic and ideas to understand problems or in a broader sense to classify information for long term memory. Conceptualization involves systematic planning and gaining an understanding of the relationships between pieces of knowledge, specific to broader ideas and theories. Conceptualization requires time to logically analyze ideas and information presented, to systematically plan, and to act on deepening intellectual understanding of a situation. Thus conceptualization seems incompatible with the cycles presented by Kolb or Bloom. Conceptualization also provides a framework for long-term memory of a subject – concepts survive as details fade.

Through our continued use of PBL for several years, we consistently find that conceptualization can take so much time that it needs to re-positioned in the learning cycle. In fact it reemphasizes the need to consider the ideas put forward by Edelson in 2001 on Learning for Use, LfU[8].

The LfU framework emphasizes learning activities that develop useful knowledge. We contend that useful knowledge is contained in the form of concepts that produce models and theories. The LfU approach addresses two significant challenges to teaching: fostering engagement and ensuring that learners develop knowledge that will be useful at future times. We have found conceptualization spurs enthusiastic engagement and supports subsequent re-use of that knowledge at future times – even years later.
As Edelson points out: "The four principles are:

1. Learning takes place through the construction and modification of knowledge structures.
2. Knowledge construction is a goal-directed process that is guided by a combination of conscious and unconscious understanding goals.
3. The circumstances in which knowledge is constructed and subsequently used determine its accessibility for future use.
4. Knowledge must be constructed in a form that supports use before it can be applied."

Conceptualization if it is properly used can provide the three step process envisioned by the LfU learning model: *Motivation*: conceptualization establishes a perceived need for new understanding, *Knowledge Construction:* building new knowledge structures in the context of evolving concepts links this "new knowledge" to existing knowledge that provides capacity to manipulate concepts by expanding them, adding new concepts to memory, subdivide concepts, or make new connections between concepts, and finally *Knowledge Organization*: organizing and connecting knowledge structures to support use. This step in learning provides future accessibility and applicability of knowledge in order to support its future retrieval and use[9-14]. In several PBL based courses, as exemplified by Heterogeneous Catalysis and Atmospheric Chemistry and Engineering, we have been using conceptualization at multiple levels to accomplish learning for lifetime use. This requires the use of conceptualization as an overlapping activity for all the learning steps. This is best perceived by examining the cyclic relationship between Kolb's model and PBL.

Comparison of Learning Cycles

Thus comparing the learning cycles, considering the importance of conceptualization and the extended time for it to occur, it is suggested that concept formation be made centric to the learning cycle process as shown in Figure 3. Here concept formation is constantly being addressed as the student moves around the loop. At the beginning of the class the students are challenged to develop a unifying concept for learning. This usually requires some prompting from the PBL mentor. Within the first class period and allowing the

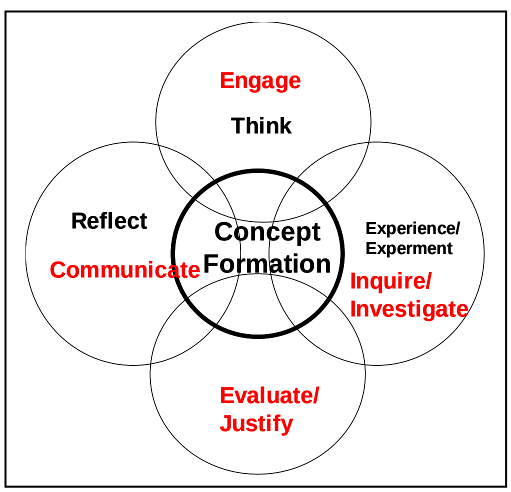

Figure 3. Comparison of Kolb's learning steps with PBL steps. PBL in red.

students to use the electronic resources and readily available content from the Internet, the class can achieve a unifying concept that helps form PBL learning groups and defines the scope and nature of content that the course will cover. This not only provides students with immediate content ownership but also gives the student a basis for organizing and connecting knowledge structures, establishes a perceived need for new understanding, and provides initial capacity to manipulate information and budding concepts.

The Atmospheric Chemistry and Engineering Example

The typical course outline is illustrated in the Table 1. Note that the course starts with the history of atmospheric chemistry and moves to atmospheric chemistry of other planets. This is feeding content to the student without a "learning for use" plan. This content will be difficult to recall as the student moves into the future. The topics seem unrelated to the main stream functional model of environmental chemistry: the study of sources, reactions, transport and fate of chemical species in the environment. The lack of a unifying concept is obvious.

Table 1: Typical Course Outline for Atmospheric Chemistry and Engineering

History of atmospheric chemistry	Alternatives to fossil fuels
Atmospheric chemistry of other planets	Lightning as a natural source of NO_x
Evolution of the Earth's atmosphere	Industrial air pollution abatement technology
Upper atmosphere physics and chemistry	Coupling atmospheric transport and chemistry
Atmospheric radioactivity	Human health effects of atmospheric pollution
Biosphere-atmosphere interactions	Cloud chemistry
Radiative transfer	Heterogeneous chemistry
Combustion chemistry	Ocean-atmosphere interactions
Biogenic hydrocarbons and ozone formation	Atmospheric composition and climate

First, the student needs to be reminded that chemistry is the unifying theme in an atmospheric chemistry course. Chemistry is reaction based. Reactions need to be the catalysts of concepts and thus need to be the central issue visited and revisited as the students progress around learning cycles. Utilizing the concept of environmental chemistry as touted by Stanley E. Manahan allow the students the opportunity to perform the three steps in LfU. Environmental Chemistry is the study of the sources, reactions, transport and fate of chemical species in the environment[15]. As one develops the problems in the concept centered PBL Cycle using the examination of the photochemistry, acid- base chemistry, free radical chemistry and homogeneous and heterogeneous catalytic cycles is revisited many times during the course.

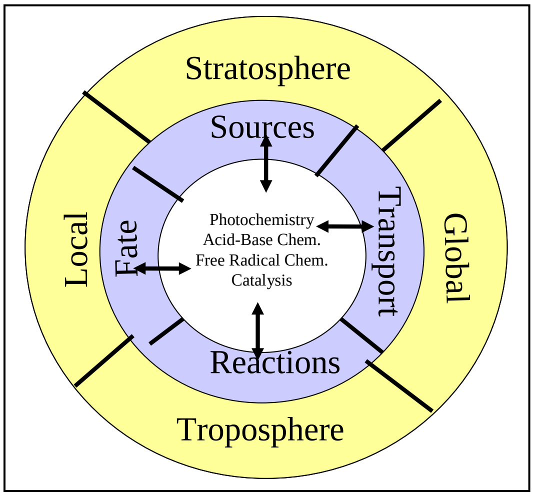

Figure 4. Content interactive strategy for PBL and Kolb learning cycles in Atmospheric chemistry and Engineering.

Conclusion

Constructivism practiced as PBL, experiential learning, inquiry based learning etc needs to move conceptualization from the learning lops and cycles to a place of central importance that allow conceptualization to begin immediately and continuously evolve and improve throughout the course. This will ensure the vest opportunity for creative thinking and long-term accessibility to learned-useful-knowledge.

Acknowledgments

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