The Convergent Classroom for Best Practice Pedagogy in Chemical Engineering Education

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Abstract

Evolving from an NSF supported activity to combine problem-based learning with modern computer based modeling and simulation is the convergent classroom that optimizes convergent technologies, content and best practice pedagogy. Convergent technologies involve computer based hardware and software, wireless networking, multimedia, hypermedia, Internet, virtual reality, interactive TV (iTV), digital TV (DTV), satellite and advanced classroom gadgetry. Convergent content combines conventional books, lecture notes, and video with digitally based information on CD’s and DVD’s, on-line laboratory experiments and demonstrations both locally and globally via the internet, internet based information resources, classroom recording of ideas from convergent and divergent thinking, discussions and group activities using visual, audio and text authoring software. The convergent classroom is allowing the same and new content to be presented via multiple ways on different platforms and to be saved for future use in digital asset banks and warehouses using multiple means of storage and use. Convergent best practice pedagogy is optimized in the convergent classroom to allow problem-based learning, objective based learning, cooperative learning, project based learning, accelerated learning, visual learning, constructivism and Socratic learning. The classroom is designed to optimize the five basic types of thinking: cognitive, memorative, convergent, divergent and evaluative - to produce the creativity and idea generative capacity often missing from conventional classrooms. The design and operation of the convergent classroom will be discussed, as well as how it is being used to optimize chemical engineering education.

Introduction

The convergent classroom is a relatively new descriptor of the high technology classroom that is emerging with great potential to enhance the learning of engineering students and faculty. This paper results from a National Science Foundation funded Course, Curriculum and Laboratory Improvement Program¹ to adapt and implement computer aided problem-based learning (CA-PBL) in Chemical Engineering education at Lamar University, using computer technology. This work was preceded by a funded project at Lamar University to examine the pedagogy and the classroom design of computer and video aided teaching (CAVAT) in 1990. Computer generated
visualizations and video, what the student sees, and simulations, what the students are expected to do, needed to be linked by models in a technologically advanced classroom. The pedagogy envisioned and the classroom design for that project exceeded the available software and hardware technology of a decade past. Today, much of the needed technology is becoming available and best practice pedagogy (BPP), that is very complementary with the technology, can be a powerful guide to technology based classroom innovation. Best practice pedagogy, defined as the best of the art and science of teaching, utilizes research, theory, the study of learning, and the history and philosophy of education. Chemical engineering education utilizes three interdependent processes: curriculum, content and pedagogy. Curriculum and content are responsible for making available the three main pillars of process chemical engineering: design, control and optimization. Curriculum, content and BPP are being revolutionized by the new computation, information and communication technologies that are converging in the classroom. These are creating fundamental changes in content platforms, pedagogical processes, learning management and assessment & evaluation - the four basic areas of classroom practice as seen in Figure 1. Each of these areas encompasses a number of important elements that must be examined in the context of the technological impact and educational technology that is driving the development of the convergent classroom. This is the principle subject of this article.

Four Basic Areas of Classroom Practice

Pedagogical Processes - BPP

Traditional teacher-centered classroom methods appear to be out-of-step with information technology and BPP, where student activity is maintained or heightened by group work and where finding and providing answers to motivating questions inspire individual study. Students now have extensive educational aids to choose from, which are not necessarily tied to the classroom or the school itself and tend to make the traditional classroom and teacher-centered lecturing passé. Student-centered BPP such as: problem-based learning (PBL), objective based learning, cooperative learning, project based learning, accelerated learning, visual learning, constructivism, Socratic learning, and the modern classroom potentially can revitalize student and faculty learning activities and improve pedagogical practice. Student-centered pedagogical processes that are both active and contextual are PBL and project based learning, processes the authors 2-7 are exploring and seeking to integrate into the convergent classroom. PBL is undergoing a renaissance in engineering education 4 and precedents exist for the incorporation of computer-aided modeling and simulation into the process exemplified by the work of Smith 8 at

**Figure 1. Four main classroom processes in engineering education**
the University of Minnesota. He has incorporated computer based modeling technology into a problem-based freshmen course. Problem based learning is ideal for chemical engineering since it parallels the general order of the scientific method: 1) identification of the problem, 2) definition of the problem, 3) formulation of hypotheses, 4) projection of consequences and 5) testing the hypotheses. The process of problem-based learning is:

- Students confront a problem that they have helped to identify
- Students, working in well-defined groups, organize prior knowledge and attempt to identify the nature of the problem
- Students pose questions about what they need to delineate to gain understanding
- Students formulate a strategy to solve the problem and identify the methodology and resources they need
- Students continue to gather and process information as they work to solve the problem.

Objective-based learning, the method of setting learning objectives, is being adapted to student centered learning using on-line computer methods such as WebLearn by Fernandez\textsuperscript{9}. Here enhanced understanding and deepened learning is encouraged by technologically improving the assessment and feedback cycles.

Accelerated learning\textsuperscript{10}, the method involving: motivating the mind, acquiring information, searching out meaning, triggering memory, exhibiting what is known and reflecting on how it was learned, is being strongly impacted by technology. Accelerated learning, which is rationalized by examining Gardner’s eight distinct intelligences: linguistic, logical-mathematical, visual-spatial, musical, bodily-kinesthetic, interpersonal (social), intrapersonal and naturalistic, has several elements that are particularly impacted by technology. Engaging as many senses as possible promotes full utilization of the intelligences and emotional learning systems. Many of these are accessible to convergent technology. One of the most important of these is the visual sense.

Visual learning, the use of static and dynamic images to enable and enhance learning, is ideally suited for convergent technologies. For effective learning, the right-brain with its connections, associations, and groupings must be integrated with left-brain precision, logic and deductions through visualization. Visuals suggest patterns that allow students to explore, engage and complete the meaning of scientific and engineering content.

Constructivism is a philosophy of learning founded on the premise that, by reflecting on one’s experiences, understanding is constructed\textsuperscript{11,12}. The constructivist idea is that the dominant metaphor in education should be the student-as-worker. The supporting idea is that the student's work should engage complex information resources capable of sustaining authentic inquiry to help them develop and integrate new understanding into their knowledge and skills. This impacts the three main pedagogical pillars of curriculum, instruction and assessment. Constructivism impacts curriculum by calling for the strong modification of a standardized curriculum and promotes using curricula more customized to the students' prior knowledge and hands-on
problem solving. Constructivism impacts instruction by requiring educators to focus on making connections between facts and fostering new understanding in students. More reliance on open-ended questions and dialogue among students is encouraged. Problem based learning as pointed out by Duffy and Cunningham\textsuperscript{12}, is an instructional model that exemplifies the constructivist theory and is a good tool of constructivism. Constructivism calls for the modification of standard grading methods and standardized testing and allows the assessment to become part of the learning process, empowering students to play a larger role in judging their own progress. Each student (faculty) is encouraged to generate their own "rules" and "mental models," which they use to make sense of their experiences. Learning, therefore, is the process of forming and adjusting mental models to accommodate new experiences\textsuperscript{13}. The emerging technology in the classroom is enhancing the formulation and archiving of the student and faculty generated models.

Socratic learning, a conversation or a discussion, wherein two or more people assist one another in finding the answers to difficult questions, is ideal for the group oriented, student-centered learning promoted by PBL. The convergent classroom that allows the division of the class into small working, but connected independent groups, is advanced by classroom communication systems\textsuperscript{14}.

According to Daniels and Bizar\textsuperscript{15}, these BPP approaches can best be achieved in a best practice classroom that provides for the following structures: integrative units, small group activities, representing-to-learn, classroom workshops, authentic experiences and reflective assessment. These structures are ideal for technological exploitation in the convergent classroom.

Content

The undergraduate chemical engineering curriculum typically encompasses the following chemical engineering courses: material and energy balances, thermodynamics, transport phenomena (often separated into fluid mechanics, heat transfer, and mass transfer), kinetics (or reactor design), process control, plant design, analysis, and unit operations laboratory. Each of these classes contributes more or less directly to one or more of the three pillars of chemical process engineering: design, control, and optimization. In particular, process design relies heavily on the concepts taught in thermodynamics (to determine whether or not a proposed process is even possible), material and energy balances (to develop the process flow sheet), transport phenomena (to move fluids and heat, and to design separations), kinetics (to design the reactors), unit operations laboratory (to become familiar with lab-scale versions of industrial units), and plant design (to learn shortcut design procedures and to practice designing processes). Process control depends on the material covered in both transport phenomena and kinetics classes (to develop mathematical models and then transfer functions for the process) as well as on, naturally enough, process control class. Finally, process optimization relies on plant design (since the process cannot be optimized until it is designed) and analysis (to model the process mathematically).

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At Lamar University the undergraduate chemical engineering curriculum has in recent years been augmented by the addition of two classes: a sophomore-level CAMS (Computer-Aided Modeling and Simulation) class, and a senior-level Advanced Process Control class. The CAMS class covers both mathematical software (POLYMATH and Mathcad) and simulation software (Aspen Plus and Pro/II). The rationale for adding CAMS to the undergraduate curriculum is that this class contributes directly to the process design and process optimization pillars, since both of these depend heavily on the simulation of the process. The Advanced Process Control class covers advanced concepts not usually covered in undergraduate process control, including Dynamic Matrix Control software (Aspen DMC), and therefore it contributes even more than the regular process control class to the process control pillar. In the CCLI classroom, visualization, virtual reality hypermedia and hypermodel tools are being developed or exploited. In particular, software applications which allow individuals to create their own e-learning content, without programming skills are being explored utilizing such tools as Authorware, ToolBook and Quest and specific visualization software such as SectorWare. Generally these include templates or metaphor approaches such as books, forms, timelines, flow charts or image authoring. Many other more specialized authoring tools are built into available learning management systems. Particularly apropos to content models is mindtools, as discussed by Jonassen, that allow learners to create their own hypermedia and hypermodel knowledge bases that reflect their own understanding of ideas. It is projected that content modeling by both student and faculty will stimulate creative thinking, so essential to the practicing chemical engineer.

Learning Management

Learning management’s importance has spawned numerous commercial ventures. A commercial Learning Management System (LMS) is software that automates the administration of training events from login of registered users to providing reports to management. LMS may include functions such as: authoring of content, management of classroom training, instructors and resources, competency management and learner collaboration tools (mentoring, chat, discussion groups, etc.) and the evolving development of models. These commercial packages provide beyond their inherent value insight into the essential elements in technology aided or centered classroom oriented learning management. According to Draper, learning depends heavily on the direction of the learner's effort, and management of the learner's activities is crucial to learning achievement. It is particularly important in the convergent learning environment where information is so easily accessible and the speed of information gathering is so fast that it may interfere with the required investment of the student in time and mental effort to learn. The learning management process must be interactive in nature and inspire the investment in time and mental effort. BPP and the convergent classroom require that the student takes substantial responsibility for learning management and is empowered to accomplish this by the blending of technology and pedagogy. Interactive management of learning needs to follow how well students are learning the material and how well the management process is succeeding. Technology aids in the information flow about how the course is going and what activities are failing and what are succeeding. This is the realm of assessment and evaluation.
Assessment and Evaluation

There are various forms of authentic assessment methods that provide multiple approaches to measuring learning through multiple observations and many different types of evidence. The ingress of technology into the classroom is making authentic assessment more accessible and is allowing rapid feedback to the student. However, it is introducing some questions that need to be researched. According to Horwitz\textsuperscript{25-29} the following need study: how can we reconcile an approach that encourages collaborative problem solving with the requirement to assign individual grades, how can the use of interactive simulations be adapted to individual learning styles and skill levels and what depth of content knowledge is required to enable faculty to feel comfortable in assigning open-ended exploratory activities. Slattery\textsuperscript{30} summarizes characteristics of emerging curricular models such as laboratories, interviews, multisensory projects, virtual and electronically connected laboratory experiments in the classroom, seminars, workshops, and field experiences that can be integrated into the technology based classroom and used in authentic assessments. Technology applications can be used as valuable tools to facilitate collecting, analyzing and accessing a variety of assessment data. Online assessment systems can provide teachers and students with detailed information on individual or group progress in easy to read reports, charts and graphs. Information from these reports can be used when making decisions about individualized learning activities. Thus, BPP learning based on ‘educational technology’ is no longer predominantly teacher-led, but rather is student-centered learning guided by efficient assessment. Educational technology explores and facilitates innovative and effective uses of technology in teaching and learning. Using the definition of the Association for Educational Communication and Technology, educational technology is a complex, integrated process of people, procedures, ideas, devices, and organizations, for all aspects of human learning. It is not technology in education or instructional technology but these are becoming increasingly important in educational technology, as it impacts instructional design, educational applications of computer technologies, educational application of telecommunications and even curriculum improvement. The convergent classroom is becoming a reality based on educational technology.

Convergent Technology

Convergent technology is the functional integration of audio, visual, computing, and communication technologies\textsuperscript{31}. Internet access is becoming standard. Digital technologies are enabling creation of interactive media-rich content. Increasing bandwidth and better delivery platforms make e-learning more attractive. A growing selection of educational technology products and emerging technology standards are facilitating compatibility, usability and increased access. Educational function requires that user-friendly control systems be an integral part of the classroom design that contains considerable hardware and software\textsuperscript{32}. Convergent technologies involve computer based hardware and software, wireless networking, multimedia, hypermedia (simply an extension of hypertext that incorporates other media in addition to text), hypermodels, Internet, virtual reality, interactive TV (iTV), digital TV (DTV), satellite and
advanced classroom gadgetry. Hypertext, non-linear writing in which you follow associative paths through a world of textual documents, is the presentation of information as a linked network of nodes which readers are free to navigate in a non-linear fashion. The linking of related pieces of information by electronic connections by hypermedia is, however, insufficient in the convergent classroom. Hypermodel, the embedding of simulations and visualizations within curricular materials to create a new kind of interactive curriculum tool, is a new linking mechanism that promises to eventually integrate the convergent classroom and the curriculum. Pedagogica is an example of this hypermodel. A sampling of potential software being explored in the CCLI project for the convergent classroom is given in Table I.

Table I. Some of the computer technology being explored for the convergent classroom

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Software</th>
<th>Internet References &amp; Comments</th>
</tr>
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<tbody>
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<td>Hypermedia</td>
<td>HyperPublish</td>
<td><a href="http://www.hyper-publish.com/">http://www.hyper-publish.com/</a> Creating a professional catalog, a Web site, a multimedia / hypermedia autorun CD.</td>
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</tr>
<tr>
<td>Learning Management</td>
<td>Informetica</td>
<td><a href="http://www.informetica.com">http://www.informetica.com</a> A learning management system allowing instructors to create, manage and deliver course content and exams online.</td>
</tr>
<tr>
<td>Assessment Evaluation</td>
<td>Testcraft</td>
<td><a href="http://www.testcraft.com">http://www.testcraft.com</a> Measuring knowledge and understanding</td>
</tr>
<tr>
<td></td>
<td>Mindtools</td>
<td><a href="http://tiger.coe.missouri.edu/~jonassen/Mindtools.pdf">http://tiger.coe.missouri.edu/~jonassen/Mindtools.pdf</a> Applications that allow learners to represent what they know, thereby engaging them in critical thinking.</td>
</tr>
<tr>
<td>WebLearn</td>
<td>WebCT</td>
<td>Web Course Tools is a set of tools that facilitates the creation of World Wide Web-based educational environments</td>
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The Convergent Classroom

Classroom design for higher education has traditionally been very conservative with the front facing classroom as its base. Adding computers on tabletops in long rows in computer classrooms has not helped the BPP and defeats group activities. BPP, and especially problem based learning, demands very flexible classroom designs including: a level floor, movable seats and tables, no central seminar table, easy access to writing boards and a design that still allows instructor focused lecturing in special events. Additional demands on the classroom design architecture are made by adding technology such as electronic based multi-media and computer aided learning methods. The convergent classroom concept envisions at its heart (see Figure 2) a flexible site that integrates content, pedagogy and technology into a functional learning facility. Its flexibility allows it to adapt to any of the BPP scenarios that the instructor deems appropriate to achieve the learning objectives. In terms of pedagogy, it needs to provide an environment for thinking and strive to optimize the five basic types of learning - cognitive, memorative, convergent, divergent and evaluative - to produce the creativity and idea generative capacity often missing from conventional classrooms. It must provide for content delivery on the most modern platforms yet not destroy the social aspects of the classroom environment. It should integrate technology into the classroom in a flexible manner that allows maximum flexibility in learning management. The instructor should strive to: a) understand the new technologies, b) develop teaching and learning strategies across media, c) develop instructional design skills, d) learn authoring and writing skills,
e) learn to construct content from learning objects and f) develop skills to edit learning objects for custom content. As seen in Figure 3, it provides for extensive blended learning that combines two or more delivery strategies to provide more integrated and effective learning experiences that build student capacity for critical thinking. It makes textbook, literature and lecture information instantly available, integrated with e-information, live or simulated research, visualization, simulation and extensive skill development activities. Ultimately technology that allows this to happen will provide for multimedia digital archiving. The latter replaces note taking and its coincidental lack of student focus. The convergent classroom differs significantly from the distance-learning classroom that is built on the traditional lecture scenario but excels in synchronous, or live learning. Synchronous e-Learning, such as Centra, PlaceWare and others goes beyond the distance learning classroom and can provide instant feedback on a student’s performance. However synchronous e-Learning is not self-paced and requires considerable learning management. Much can be gleaned from the distance learning classroom and synchronous e-learning in the development of the convergent classroom. In the design of the new convergent classroom, experience with an NSF funded prototype multi-electronic media classroom proved invaluable to catalyzing classroom innovations. A short description of the prototype classroom will provide insight into the ultimate design of the convergent classroom.

Prototype Classroom

Classroom Architecture: A small prototype computer based classroom\(^4\) to test the principles of CA-PBL has been in operation for two years. It is served by a CISCO Aironet 350 Wireless Networking System. The main server for the instructor is a Gateway E-4600 SE with Windows 2000 Server. The classroom is structured to support three problem-based learning groups. Each group has 5 Client Computers - with Windows 2000 Professional. Each group also has a 4’x 6’ electronic white board (smart board) to electronically capture “chalk board” discussions. The electronically smart white boards allow the instructor and PBL groups to use projection screen support to make the white boards as touch-sensitive projection screens by connecting to PC and LCD projector, to save everything written or drawn in various colors on the board instantaneously to PC’s or storage media, to send e-mails, or to post notes directly to the department web site to share with colleagues world-wide, and to involve real time teleconferencing with remote participants. The instructor has an electronic white board that is in active control of the computer through a Toshiba TPL 671 LCD Projector with overhead camera. This LCD projector has been an important transitioning unit in the classroom since it allows textbook materials and transparencies to be projected. Such a projector has also allowed instructors beginning with PBL to use traditional materials such as overheads, textbooks and written notes. This has been essential to getting established faculty to actively participate in PBL and the new classroom. WebCams are also used for videoconferences with individual groups from remote locations. It also allows material to be digitized and transmitted to the class by e-mail or other digital recording media. This has to a large extent removed the burden of students’ manual note-taking since virtually all materials can be electronically based or electronically captured and e-mailed to the students. The students are free to concentrate on the information being discussed in class and this aids considerably in promoting PBL working...
groups’ activities. The era of the paperless classroom has been proven a reality in the prototype classroom.

Design of the Convergent Classroom

The use of the prototype electronic classroom described above has resulted in the design of a new classroom shown in Figure 4. This new classroom will be incorporated in our program for engineering and science education. It goes beyond the “conventional” electronic classroom and adds a dimension of separation of groups, yet maintains the unity of an instructor-controlled classroom. It requires that the instructor be located in the center of the classroom with a podium containing a master server, web camera, and digital projector with camera. Located above the podium will be four plasma computer screens that are connected to the master server and can be controlled as a unit or separately to provide visual information to each group. Each PBL group will have six computers and an electronic whiteboard. These will be used in group discussions. The master server will monitor all white boards and all computers. This will allow instructor participation in the group activities. After PBL groups form, there is a need for the instructor to meet periodically with each group, for mentoring and tutoring. These meetings can be face-to-face, by conference call, by chat room or web meeting or can take place in the convergent classroom. The dominance of information collection and processing in the PBL process is ideal for the use of electronic resources for collection, compilation and utilization of this information. In the PBL process being used in Chemical Engineering the information generated by a particular group is generally stored and made available to the class in the form of Power Point Presentations. These are placed on the Class’s web page site and can be accessed by the entire class. Students also maintain individual folders on the web site, which allows monitoring of each student’s contribution to the information manipulation. Also, it is quite common to have the groups functioning in the classroom and this is where proper classroom design in paramount. Figure 4 shows the convergent classroom design that optimizes BPP and
incorporates the convergent technologies. It will also use Polycom iPower 970 conferencing technology to bring distance learning capabilities with maximum versatility. This technology was developed with Intel to allow distance and local classroom-to-classroom discussions, student presentations, Web surfing, document collaboration, e-mail and database.

**CURRICULUM MODIFICATION**

The availability of the convergent classroom and the practice of CA-PBL is spurring the redesign of the Chemical Engineering Curriculum Course flow as shown below in Figure 5 following the introduction of a new second year course, CAMS. This has become a true “Path-finder Course”. CAMS integrates PBL and other BPP into the chemical engineering curriculum with an implementation of computer-aided modeling and simulation packages. CAMS, which introduces CA-PBL in the sophomore level and concludes at a senior course of Advanced Analysis, is providing a new unifying view of chemical engineering for second year students and providing new skills for second year Co-oping. It introduces students to two types of computer packages: mathematical packages (MathCad and POLYMATH) and simulation packages (Aspen and ProII) using exemplary problems to be faced in forthcoming classes. The students use the mathematical packages to solve specially selected math problems that typically arise in upper-level chemical engineering classes such as regression (both linear and nonlinear), nonlinear equations, and systems of ordinary differential equations. They also are exposed to problems to be addressed in the upper classes. The remainder of the semester is devoted to familiarizing the students with the simulation packages. Since these sophomore students have not yet had any chemical engineering courses (except the material and energy balance class, which they take concurrently), some time is spent describing the theory behind such common unit operations as flash drums, heat exchangers, chemical reactors, distillation columns, etc., as well as the theory behind each package’s solution algorithm. Details are left to later upper-level classes, after the students have been introduced to the required fundamental theory. However, problems in several junior and senior courses are given in this class and solved by computer packages. Starting CAMS teaching at a stage as early as the sophomore level is quite new in chemical engineering curricula. However, after two and a half years experimenting, the NSF-CCLI implementation project finds that the advantages are substantial. The first advantage is to help students in the co-op program and in the Process Analysis Course (Material and Energy Balance). Most of our co-op students use one of the Computer Aided Modeling and Simulation packages (such as ASPEN, PRO II, and HYSYS).
during the co-op time period. CAMS prepares them early enough that they are able to move into the work situation quickly to solve practical problems in industry. Returning co-op students have a “problem based learning” pedagogical mind-set and more appreciation learning the fundamental principles in junior/senior engineering basic courses. This helps to pave-the-way for PBL pedagogy in the chemical engineering curriculum. CAMS is a pathfinder for PBL and the curriculum flow shown in Figure 5. The NSF-CCLI implementation project has found that the co-op students can learn the fundamental principles more effectively than the non-co-op students. This could be a difference between the learning pedagogies of science and engineering education. In other words, the engineering students feel the need to learn fundamental principles in order to solve problems. Another advantage of CAMS is to prepare the students for the chemical engineering sophomore (Process Analysis), junior (Thermodynamics, Momentum Transfer, Heat Transfer, and Kinetics) and senior (Mass Transfer, Plant Design, and Process Control) courses in problem based learning with an implementation of computer aided modeling and simulation. CAMS teaches the students to do a process simulation for the units of Mixers, Separators, Heat Exchangers, Columns, Reactors, and Pressure Chargers. These units are the applications of Process Analysis, Momentum Transfer, Heat Transfer, Mass Transfer, and Kinetics. Besides, the selection of the thermodynamic models prepares the students to learn a non-ideal mixture of chemical compounds that will be studied in Thermodynamics. With CAMS preparation, students are assigned problems closer to the real world. The instructors can encourage the students to experiment with different operating variables to understand fundamental principles. The curriculum revision inspired by the concept of the convergent classroom calls for development of new educational material for the prototype course, CAMS, so that the advantages of learning in the chemical engineering program can be realized.

CONCLUSIONS

Consideration of the convergent classroom gives a futuristic view of engineering education. It focuses attention on the strong interrelatedness of best practice pedagogy, educational technology, technology in the classroom, and curriculum design and improvement. The convergent classroom poses challenges for administrators, educators, students and classroom designers. The change from instructor-centered to student-centered, computer aided pedagogical approaches such as simulation and modeling PBL in higher education is facilitated by convergent technology and pedagogy. However, convergent classrooms must be carefully designed to meet the pedagogical objectives and may require curriculum change. In the case of CA-PBL, the modern multi-electronic classroom is essential for optimization of the PBL process and to develop critical thinking. The convergent classroom can provide a multidimensional experience for the learner and teacher that enhance the rate, depth and quality of learning. CA-PBL has inspired a new pathfinder course CAMS in the ChE Curriculum and a reevaluation of curriculum flow. The new convergent classroom is emerging today as a powerful force in engineering educational technology.
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