6-26-2011

Multi-Disciplinary Project-Based Paradigm That Uses Hands-On Desktop Learning Modules and modern Learning Pedagogies

William David Schlecht
Washington State University

Bernard J. Wie
Washington State University

Paul B. Golter
Washington State University

Robert F. Richards
Washington State University

Marc Compere
Embry-Riddle Aeronautical University, comperem@erau.edu

See next page for additional authors

Authors
William David Schlecht, Bernard J. Wie, Paul B. Golter, Robert F. Richards, Marc Compere, and et al.

AC 2011-878: MULTI-DISCIPLINARY PROJECT-BASED PARADIGM THAT USES HANDS-ON DESKTOP LEARNING MODULES AND MODERN LEARNING PEDAGOGIES

William David Schlecht, Washington State University

William Schlecht is an undergraduate student at Washington State University studying chemical engineering. He got involved with the DLM project at the beginning of his junior year and has been working under the guidance of Bernie Van Wie for a year and a half. William intends to earn a Ph. D. with and work in the biotechnology industry.

Bernard J. Van Wie, Washington State University

Prof. Bernard J. Van Wie did his B.S., M.S. and Ph.D. and postdoctoral work at the University of Oklahoma where he also taught as a Visiting Lecturer. He has been on the Washington State University faculty for 28 years and over the past 14 years has focused strongly on innovative pedagogy along with his technical research in biotechnology. His recent Fulbright Exchange to Nigeria set the stage for receipt of the Marian Smith Award given annually to the most innovative teacher at WSU. (509) 335-4103 (Off); (509) 335-4806 (Fax); bvanwie@che.wsu.edu.

Paul B Golter, Washington State University

Paul B. Golter obtained an MS from Washington State University and recently defended his PhD degree and is currently the Laboratory Supervisor in the Voiland School of School of Chemical Engineering and Bio-engineering at WSU. He is married with three children.509-338-5724.

Robert F. Richards, Washington State University

Dr. Richards is a Professor in the School of Mechanical and Materials Engineering at Washington State University.

Jennifer C Adam, Washington State University
Ashley Marie Ater Kranov, Washington State University

Dr. Ater Kranov is Director of Educational Innovation and Assessment for the College of Engineering and Architecture at Washington State University, USA. She is affiliated assistant professor in the School of Electrical Engineering and Computer Science where she co-teaches the 2-semester senior design capstone sequence.

The paper describing her collaborative work with faculty in the WSU College of Engineering and Architecture, "A Direct Method for Teaching and Assessing the ABET Professional Skills in Engineering Programs", won the 2008 ASEE Best Conference Paper Award. She has served as evaluator on a number of multi-institutional, interdisciplinary NSF sponsored grants. She is principal investigator on a NSF Research and Evaluation on Education in Science and Engineering project called "A Direct Method for Teaching and Measuring Engineering Professional Skills: A Validity Study."

Dr. Marc Compere, Embry-Riddle Aeronautical Univ., Daytona Beach FL
Dr. Edwin Maurer P.E., Santa Clara University
Denny C. Davis, Washington State University

Dr. Davis is Professor of Bioengineering and Director of the Engineering Education Research Center at Washington State University. He is a leader in creation of assessments for teamwork, professional development, and design skills learned in the context of team projects. He is also a Fellow of the American Society for Engineering Education.

Olusola O. Adesope, Washington State University-Pullman

Olusola O. Adesope is an Assistant Professor of Educational Psychology at Washington State University, Pullman. His research interests center on the cognitive and pedagogical underpinnings of learning with computer-based multimedia resources; knowledge representation through interactive concept maps; meta-analysis of empirical research, and investigation of pedagogical practices for developing science, technology, engineering and mathematics (STEM) education.

Joseph D. Law, University of Idaho, Moscow

Joseph D. Law obtained his Ph.D. in electrical engineering from the University of Wisconsin, Madison, in 1991 and is currently an Associate Professor in the Department of Electrical and Computer Engineering at the University of Idaho. His research interests include methods to improve student learning, flywheel energy storage, and electrical disturbances in power systems.

Gary Robert Brown, AAC&U
Prashanta Dutta, Washington State University

Dr. Prashanta Dutta is an Associate Professor in the School of Mechanical and Materials Engineering of Washington State University. He received his PhD in mechanical Engineering from Texas A&M University, College Station, TX in 2001.

David B. Thiessen, Washington State University

David B.Thiessen received his PhD in Chemical Engineering from the University of Colorado in 1992 and has been at Washington State University since 1994. His research interests include fluid physics, acoustics, and engineering education.

Baba Abdul, Washington State University

Baba Abdul received an MSc. in Chemical Engineering from Ahmadu Bello University, Nigeria in 2005. He is currently a doctoral candidate in the Voiland School of Chemical Engineering and Bioengineering at Washington State University. His research interests include transport processes in minimal support helicosymmetric minichannels and aspects of engineering education (New Engineering Learning Systems & Bringing Technical Research into the classroom).

Multi-Disciplinary Project-Based Paradigm that Uses Hands-on Desktop Learning Modules and Modern Learning Pedagogies

Abstract

It has been established that traditional lectures *ARE NOT* best for student learning – yet that is what the community almost universally does! Furthermore, engineers work in broad multidisciplinary teams while classroom learning is individual and narrow. Yet, educators rarely invest the time and resources necessary to employ such innovations.

In this CCLI type II award we are further refining Desktop Learning Modules (DLMs) within a Cooperative, Hands-on, Active, Problem based, Learning (CHAPL) setting for Chemical, Civil, Mechanical, Bio- and Electrical Engineering courses at a diverse set of institutions, including a community college engaged through a distance learning mode. A workbook is being developed and tested for easier adoption of the hands-on units and accompanying pedagogy. Existing concept inventories are not always showing significant gains in apparent student learning either for control or experimental groups and we are concluding these assessments are not well aligned with the macroscale design calculations being emphasized in the course. Therefore, new concept question assessments are being developed consisting of some macroscale questions from past inventories along with conceptual essay and calculation based questions aligned more specifically with the DLM processes at hand. Past implementations like this show students learn key concepts at least as well from each other in a guided inquiry as they do from lecture. Also, a mixed qualitative / quantitative assessment using a critical reasoning rubric reveals student abilities become better aligned with what is expected of graduating engineers ready for industry and that the CHAPL/DLM environment serves to reinforce understanding of physical phenomena, and to develop analytical and evaluative problem-solving skills. Interviews, surveys and team reports reveal students are better able to visualize concepts and that classroom exercises are promoting team skills and academic rigor. Faculty interviews reveal enhanced awareness of student misconceptions and improved monitoring of student growth in conceptual understanding and interpersonal skills.

The poster and paper will highlight our findings and illustrate the CHAPL environment. Hands-on DLMs with cartridges used in teaching principles in the various disciplines will be demonstrated. A survey will be offered to those viewing the poster to assess potential interest in adoption of the DLMs and in participating in a follow-on NSF Type III proposal for Transforming Undergraduate Engineering Education through use of the DLMs and associated CHAPL pedagogies.

Introduction

In today's science and engineering classrooms passive, lecture based teaching is slowly giving way to more well rounded pedagogies such as POGIL[1] and Hi-PELE[2] that incorporate active student participation. Motivation for this paradigm shift comes from numerous findings that hands on, active learning possesses advantages over purely aural teaching[3,4]. There are several well known champions of this ideology such as Richard Felder who sites McKeachie's work when he says, "…immediately after a lecture students recalled 70% of the information presented in the first ten minutes and only 20% of that from the last ten minutes." [5]. This shows how student retention rapidly drops off in a traditional lecture. According to Hesketh active inductive style learning creates deeper and longer lasting understanding, thus helping alleviate the issue of low student learning retention[6]. Wankat, who encourages active team learning in graduate level classes, says such active group instruction increases student learning and creates a solid education experience which functions as a framework which the graduate students, who may become professors themselves, can draw from to teach future classes of their own[7]. The need for change in the basic structure of undergraduate education is summarized best by Dr. Edgerton, who says,

"Learning 'about' things does not enable students to acquire the abilities and understanding they will need for the twenty-first century. We need new pedagogies of engagement that will turn out the kinds of resourceful, engaged workers and citizens that America now requires"[8]

The "pedagogies of engagement" to which Dr. Edgerton refers are the type of active, hands on teaching methods to which this paper and research is devoted. This shift from traditional lecture based classes to more active, hands on teaching is especially impactful in classes where concepts are particularly abstract and thus difficult to visualize or relate to everyday life[9]. This adequately describes the material being taught in most science and engineering classes where it is desired to create learners skillful in hands on problem solving capable of working in multidisciplinary teams, and not those with an abstract individualistic style of problem solving.

The hands on paradigm shift began more than 25 years ago[10], yet 70-90% of professors still implement the traditional lecture format[11]. The reason for this as proposed by Felder is that most professors are experts in their field, however, not necessarily in teaching and are often unaware of or reluctant to implement teaching strategies which they themselves were not taught with[12]. In order to bring engineering education from the outdated aural style and into alignment with modern, research-substantiated pedagogies increased dissemination and diversification of existing active, hands on learning is needed.

With the aim of progressing the engineering education paradigm shift of active, hands on education a teaching method that incorporates elements of Collaborative, Hands on, Active and Problem based Learning known as CHAPL has been developed for use in engineering courses[13]. The CHAPL teaching method allows students to actively participate in their own education by literally getting out of their seats, forming teams, and working together on small scale desktop learning modules (DLMs, see figure 1) to examine class specific phenomena and equipment. The CHAPL pedagogy is collaborative because students form teams to tackle problems given to them at the beginning of class. It is hands on because the problems require physical manipulation of the DLMs to obtain necessary data. It is active because derivation of equations through discussion with peers and faculty as well as examination of the physical process being demonstrated by the DLM are needed to utilize the obtained data. Finally, it is project/problem based because the goal of all this data collection, teamwork and abstraction is to answer questions given on a worksheet at the beginning of class or to engage in a broad-based team design project where success depends on understanding the principles inherent in many or all of the cartridge options used with the CHAPL/DLM teaching approach.

Figure 1: DLM with shell and tube heat exchanger cartridge inserted. The on/off switch is located on the right side of the DLM, digital display for temperature and pressure readings are just above cartridge. The shell and tube cartridge plugs into the main module with standardized ports for quick swapping of one cartridge with another.

This paper will summarize CHAPL/DLM implementation thus far, including various methods used to assess the effectiveness of this pedagogy. The paper will go on to discuss current and future NSF sponsored efforts to improve, diversify and disseminate the CHAPL pedagogy.

CHAPL Implementation: Where We Started and What We Have Learned

The idea of CHAPL began more than 12 years ago in the Washington State University (WSU) unit operations laboratory, where originally large expensive modules were used to give students hands on experience with the equipment and physical processes they were learning about in a required chemical engineering fluid mechanics and heat transfer class[13]. The idea of CHAPL was straight forward, i.e. to apply several research backed pedagogies (collaborative, hands on, active and problem based learning) to a single class and tie this together by giving students physical examples of the processes they were learning about. The basic model of the CHAPL classroom has not changed much since its inception. Students group into home teams (3-5) to complete homework, in class worksheets and projects. Class time itself consists of teams completing

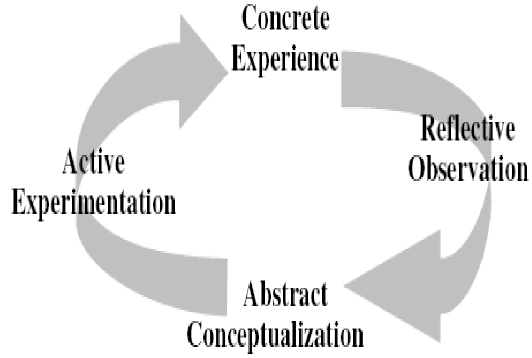

Figure 2. The Kolb Learning Cycle

worksheets that require hands on use of physical models and active data collection. Professors and teaching assistants act as preceptors and assist with clearing up confusion and guiding students to the appropriate solutions either by pointing them to the necessary sections in their text book or simply by guiding the student through the derivations needed. The focus is always on giving students an active role in their own education. One motivation for creating a class structure like this was to implement Kolb's experimental model (shown in figure 2) in a non-lab class[13]. Using the physical models students could gain concrete experience by seeing the process in action, reflect on how this related to the problems given to them in the form of worksheets, use or derive "abstract" equations that relate process variables to the desired answer and finally perform active experimentation to examine if changes made to the system are adequately predicted by the abstract models.

The bulky modules used originally were phased out in favor of compact modules that could easily sit on a desk in a standard class room. These modules were produced internal to WSU because no other module of this compact size existed, and commercial laboratory modules of reduced size (still too large for a standard classroom) cost up to $30,000[14]. These were the first desktop learning modules (DLMs), which have gone through several improvements since their creation. The current model is shown in figure 1 and consists of two 4 liter tanks each with its own pump, rotameters to measure flow, two digital readouts to show pressure and temperature readings in the cartridges and a quick release port that allows different cartridges to be interchanged easily. This is all powered by a 12 volt lead acid battery (2-3 hours of continuous operation). The module is stand alone and does not need to be plugged in to an electrical outlet or water source. Examples of the cartridges used in the fluid mechanics and heat transfer class are shown below (figure 3).

In order to assess the impact of the CHAPL pedagogy on student experience and conceptual understanding two main tools have been implemented. The first assesses students' own feelings regarding the class experience and utilizes Chickering and Gamson's 7 principles of good practice as a basis for question topics[15]. Questions based on these principles have been developed into what is known as the Flashlight Survey where the students are asked to what extent they agree regarding a series of statements about the class. Figure 4 shows the responses to this survey given by Nigerian students who were taught with HAL pedagogy for a semester (HAL stands for hands-on active learning and was the name of CHAPL at the time)[16]. The most notable features of this survey were the large number of students who felt CHAPL allowed them to visualize concepts and grasp facts better than a standard lecture. Additionally a significant number of students felt more comfortable in discussions after using the DLMs in a CHAPL setting.

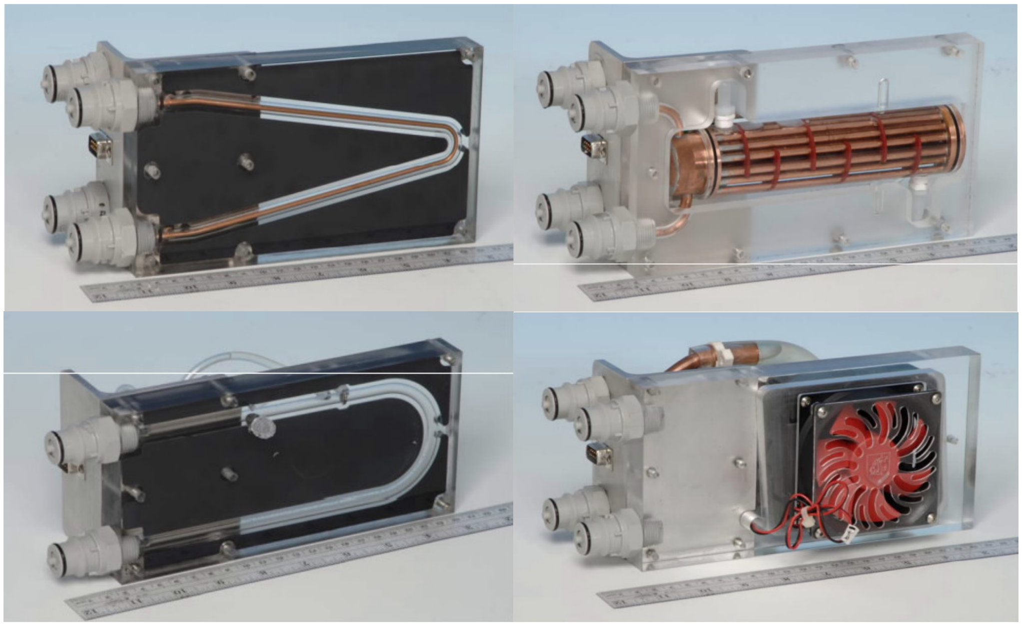

Figure 3: Example DLM cartridges, including extended area (lower right), double pipe (upper left) and shell and tube (upper right) heat exchangers as well as an orifice flow meter (lower left)

Another Flashlight survey is shown in figure 5. This was given to students in a civil engineering class that for one day utilized an open channel weir to teach water resource engineering. After this initial class implementation, students were asked about their overall satisfaction with the DLMs and 29 of the 44 students said they were satisfied and 13 said they were very satisfied. Only two of the 44 reported being less than satisfied with the DLMs.

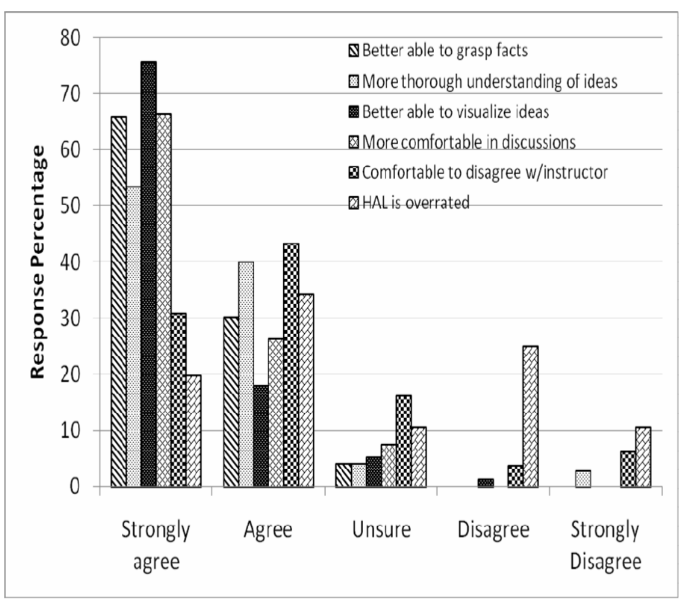

Figure 4: Flashlight Survey of Nigerian students asking them to what extent they agreed to a series of statements. The statements are given in the legend on the right side of the chart. As can be seen, a very significant number of students felt they could both visualize and understand concepts better from a CHAPL based class than a standard lecture class.

The other assessment tool, which serves to at least semi-quantitatively evaluate student gains in conceptual understanding, is the concept inventory. These short multiple choice tests allow for examination of pre and post course concept mastery in a topic. The concept inventory used for the fluid mechanics and heat transfer course where CHAPL was developed was derived from a broader Thermal and Transport Sciences Inventory[9]. Below are the results of these concept inventories when given to two separate groups of students. The transition group was taught using traditional lecture for the first half of a semester and CHAPL during the last half of the semester while the CHAPL group received purely CHAPL based instruction all semester. The CHAPL group improved on average by 30% between their pre and post course concept inventories while the transition group improved by only 21% on average.

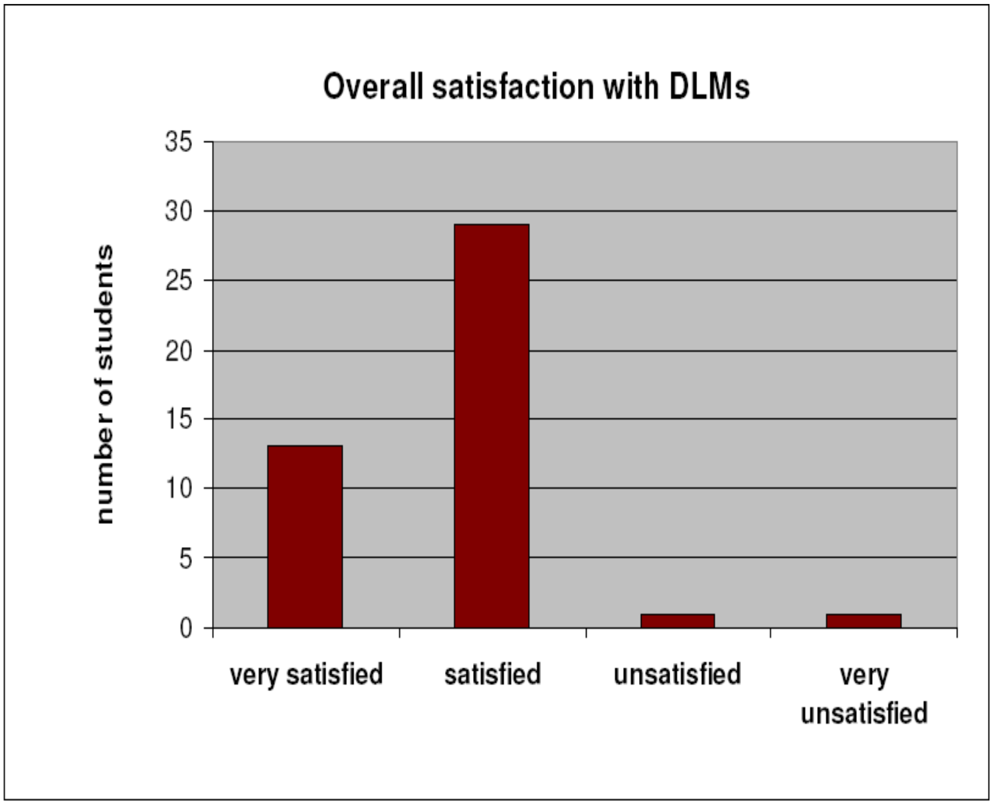

Figure 5: Flashlight survey of civil engineering students asking how satisfied they were with the DLMs

These results are typical of Flashlight surveys given to CHAPL based classes where we consistently see positive responses on the majority of questions in the 80% range or above[13].

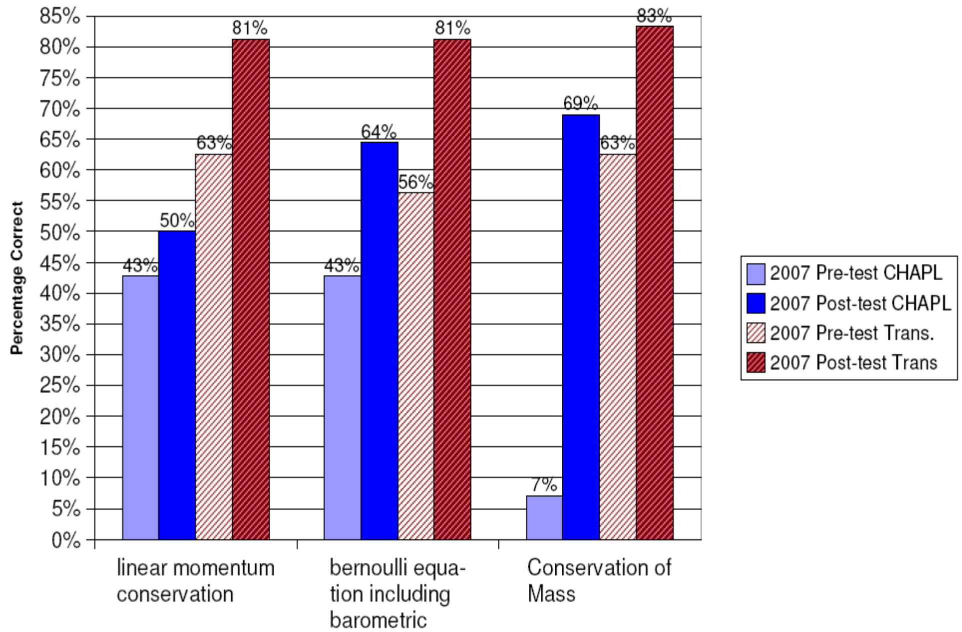

Figure 6: Pre and post course concept inventories given to a purely CHAPL taught group, and a transition group that received half lecture and half CHAPL instruction.

These two assessment methods have been used to evaluate the impact of CHAPL based instruction on student experience and concept mastery and have repeatedly shown over 80% student satisfaction and conceptual gains.

Moving Forward

The remainder of this paper talks about current and future work furthering the CHAPL pedagogy. This includes dissemination efforts and plans to expand the DLM cartridge library as well as a shift in CHAPL focus from test to project emphasis.

Work with Other Institutions

Dissemination is a primary focus of current and future CHAPL work. True to that intent WSU has plans to extend DLM/CHAPL implementation to three other programs at the host institution as well as to four additional institutions within the next 2 years. At home this will include expansion to Civil Engineering in the form of a DLM with hydraulics / water resources cartridges, Mechanical Engineering with an expanded set of fluid mechanics and heat transfer cartridges, and Bioengineering with a new set of biomedical engineering fluid mechanics and heat transfer cartridges. External institutions include a community college that will be incorporated using distance learning technology (Olympic College). This community college offers distance learning degrees from WSU and thus these CHAPL courses will be a natural addition to the distance learning program. A private university in California (Santa Clara University) will participate in implementing our new pedagogy as well as another private university in the south east (Embry-Riddle University). Embry-Riddle University will be using a DLM/CHAPL driven fluid mechanics and heat transfer class as part of a mechanical engineering curriculum and in addition will produce a solar powered Organic Rankine Cycle cartridge and water purification units. Santa Clara University will use the Civil Engineering hydraulics cartridges. We note the CE person is also likely to receive a Fulbright Exchange appointment in South America and plans to expand the pedagogy there as well. Finally, a sister, just-across-the-state-line institution (University of Idaho) plans to implement cartridges which are also capable of producing electrical power in an Electrical Engineering class. These implementations will be on a trial basis and allow the institutions to judge for themselves if the results of CHAPL pedagogy are sufficient to prompt further long term interest.

A similar trial basis CHAPL implementation was just completed at Oklahoma University. This trial class was offered on a pass / fail basis and was given as preparation for a thermal transport fluid mechanics and heat transfer course later in the year. The class was composed of 8 students, 7 of which were in the A to B grade range and 1 in the C range. The 8 students formed two teams of 4 to solve problems in an active hands on and cooperative environment aided by use of the DLMs. These students were given a pre and post course concept inventory to assess the change in conceptual understanding before and after taking the course. As done in the past these concept inventories were composed of a fluid mechanics portion and a heat transfer portion as these two components are the two core aspects of the course. The results of these concept inventories are shown in figure 7. Students participating in the course appear in Fig. 8 surrounding a DLM along with a PhD student from WSU (Baba Abdul).

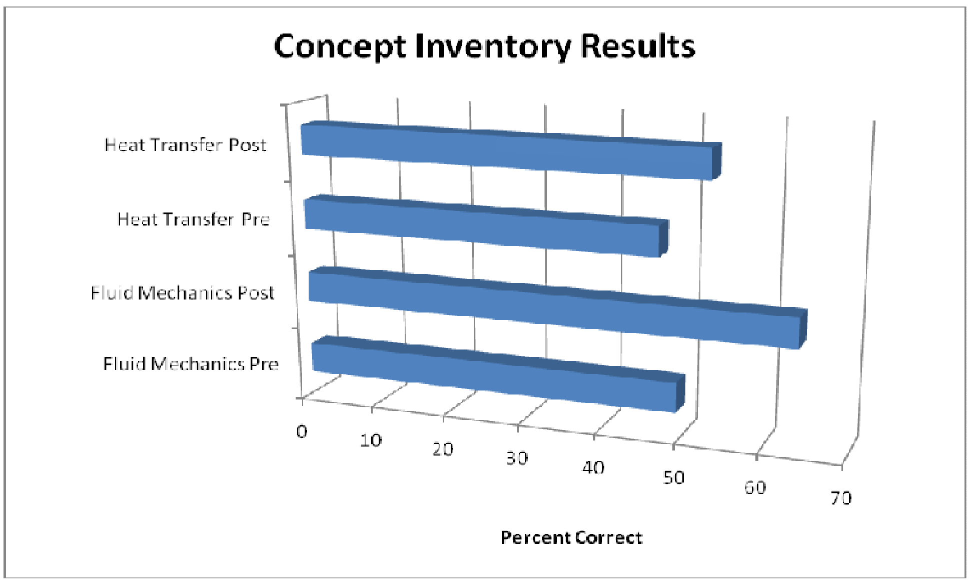

Figure 7: Results of the recent concept inventories taken by students in a trial CHAPL course. Statistically significant differences are seen between the pre and post test scores in both the heat transfer and fluid mechanics portions of the inventory.

As can be seen from figure 7, there are statistically relevant gains in the areas of both heat transfer and fluid mechanics.

One final effort to facilitate future dissemination of CHAPL pedagogy is the creation of a CHAPL interest survey. This survey will be designed to test the interest and extent of potential use of DLM driven CHAPL classes by faculty and department heads. This allows the CHAPL team to evaluate the scale of potential interest in future NSF sponsored dissemination efforts and prepare accordingly.

Figure 8: Students of the recent Oklahoma University's pre-transport series fluid mechanics and heat transfer course working with the DLM

Work at Home

Aside from dissemination, work is also focused internally on improving CHAPL itself. This is being done through refinement of assessment techniques, design of new DLMs and diversification of cartridges, creation of a standardized workbook for use with the DLMs, and even a change of CHAPL class structure from one based on tests to a project centered course. These efforts are described below.

The concept inventories used to assess conceptual gains for a recent fluid mechanics and heat transfer course showed no conceptual gains for either the control or the experimental group, this is believed to have been because of poor alignment between the macroscale design being taught and the type of questions on the concept inventory. To correct this misalignment the questions on the concept inventory are being rewritten so as to better reflect what is being taught in class, this includes some trivial terminology changes, as well as some more substantial shifts between micro and macroscale transport questions. With these changes it is expected that as has been shown before, statistically significant conceptual gains will be shown between pre and post course concept tests and that CHAPL does just as good a job as lecture at creating conceptual gains.

Another large change to the CHAPL pedagogy is the paradigm shift between test driven, and project driven classes. To better align the undergraduate education with what industry expects a change from the traditional test driven class structure to an overarching semester project driven class structure has taken place. In order to assess student performance in this new paradigm a qualitative/quantitative assessment rubric has been developed the details of which have been published in previous conference proceedings of the ASEE. Recently WSU alumni were asked several questions regarding the project prompt and the quality of the assessment rubric. The Alums were asked the following 4 questions and were told to give their answers from the vantage of an experienced engineer in industry.

1) “How accurately do the skills described above reflect the skills and knowledge required of professionals in your employ? Give your answer as a value from 1 to 6 with 1 being very inaccurately and 6 being very accurately.”

The average response to this question was 4.3 corresponding to moderately accurately.

2) “How frequently do the criteria in the rubric (in concert with the project) reflect the skills and knowledge required of professionals in your employ? Give your answer as a value from 1 to 6 with 1 being never and six being always”.

The average response to this question was 4.2 corresponding to occasionally.

3) “How important are the skills described in the previous rubric for success in the professional world? On a scale of 1, unimportant, to 6, extremely important.”

The average response to this question was 4.2 corresponding to important.

4) “From your professional vantage: To what extent does this assignment provide the student an opportunity to prepare for work in industry? On a scale of 1, greatly constrains the opportunity, to 6, greatly affords the opportunity.”

The average response to this question was 4.5 corresponding to mostly affords the opportunity.

From these questions it is seen that the project and corresponding rubric afford valuable preparation for industry. Although there was some variance in the answers given between alums, the averages represent good approximations of an industrial consensus regarding the pertinence of this project based paradigm shift in conjunction with the qualitative/quantitative assessment rubric.

Another area of work is on the DLMs themselves. These devices that provide a perfect tool to create a CHAPL environment have, since there creation, been updated and improved. With this new phase of the CHAPL project the DLM design will undergo major renovation. Designs for a new generation of DLM have already been drafted at WSU and when constructed are anticipated to be used for testing implementation in this CCLI Type II award. However, a private external company, known as a world leader in educational laboratory hardware manufacture and distribution, is also drafting ideas for a new design for the DLMs. It is anticipated these will be available for future dissemination should the researchers be successful in garnering a future Type III award from NSF. It is also possible that the newly drafted design at the host institution could be used in a national dissemination in Africa where the project director recently spent one year as a Fulbrighter and where he is affiliated with a World Bank sponsored effort to expand use of the pedagogy there.

The final area of improvement for CHAPL, as mentioned above, is in the cartridges themselves. We aim to expand the current cartridge library to include cartridges such as a solar powered heat engine and a boiler condenser cartridge. These will allow for use of DLMs in classes far outside of the usual fluid mechanics and heat transfer courses. Plans for biomedical cartridges are also in the works and will afford even more opportunities for diversification of DLM usage. The creation of new cartridges is expected to follow or be concurrent with the creation of the new generation of DLM.

Conclusion

A clearly established need for advancement in undergraduate education in the fields of science and engineering exists. This need has been well documented in literature and shows that traditional lectures are lacking in several key areas such as student learning retention, and industrial preparedness of graduates. Literature also has much to say regarding collaborative, hands on, active and problem based learning, namely that this style of learning promotes deeper understanding of concepts and improves alignment of graduates with the expectations of industry. The majority of science and engineering professors however still cling to the traditional lecture style of teaching. Motivated by this need for research substantiated and easily disseminated pedagogies the CHAPL team continues to refine its teaching method and facilitate other institutions' adoption of this pedagogy through creation of improved DLMs with an expanded range of instructional uses, as well as refinement of its assessment techniques and even a change of focus from test to project based classes. Concept inventory evaluation of CHAPL classes have continued to show that conceptual gains through the courses are significant and that CHAPL does at least as good a job at improving conceptual understanding as traditional lecture, with the additional benefit of improving soft skills such as communication and teamwork. A survey of alums from WSU shows that the project centered class work and assessment rubric are in good alignment with industrial expectations and that the work produced by students in CHAPL based courses is in good alignment with what industry would expect of entry level employees.

Acknowledgements

The authors wish to acknowledge the US National Science Foundation CCLI Grants DUE-0618872 and 1023121) for support of the work to build, test and more importantly implement the DLMs and associated CHAPL pedagogy. We are grateful to the College of Engineering & Architecture important design contributions to and manufacturing of the DLM from Mr. Gary Held, Machinist in the WSU College of Engineering and Architecture Machine Shop. We also acknowledge Prof. Howard Davis, of the WSU Voiland School of Chemical Engineering & Bioengineering for design of the DLM electronics package. We further acknowledge companion support from the World Bank for parallel implementation in an African nation.

Additional thanks is directed to Embry-Riddle University, Santa Clara University, The University of Idaho, The University of Oklahoma and Olympic College and the professors and students of those universities who participated and continue to participate in this program.

Bibliography

1. *The POGIL Project*. cited 2011; Available from: http://www.pogil.org/.
2. Arce, P. and L. Schreiber, *High Performance Learning Environments, Hi-PeLE.* Chemical Engineering Education, 2004 (Fall Issue): p. 286-291.
3. Dale, E., *Audiovisual methods in teaching*. 3 ed. Vol. 1. 1969, New York: Dryden Press.
4. Crouch, C.H., A.P. Fagen, J.P. Callan, and E. Mazur, *Classroom demonstrations: Learning tools or entertainment?* American Journal of Physics, 2004. **72**(6): p. 835-838.
5. Felder, R., *How About a Quick One?* Chem. Engr. Education 26(1), 18-19 winter 1992.
6. Hesketh, R., Farrell, S., and Slater, C., *An Inductive Approach To Teaching Courses In Engineering,* Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition.
7. Wankat, P., Oreovicz, F., *Cooperative Learning in a Course On Teaching Engineering.* Proceedings of the 2001 American Soceity for Engineering Education Annual Conference and Exposition, p. 1
8. Edgerton, R., Education White Paper, 2001, *http://www. pewundergradforum. org/wp1.html*.
9. Streveler, R., Latzinger, T., Miller, R., Steif, P., *Learning Conceptual Knowledge In The Engineering Sciences: Overview and Future Research Directions.* Journal of Engineering Education July 2008. pp 279-291
10. Smith, K., Sheppard, S., Johnson, D., Johnson R., *Pedagogies of Engagement*: *Classroom Based Practices.* January 2005, Journal of Engineering Education, pp. 1-3
11. Gardiner, S., *Why We Must Change: The Research Evidence,* HCC 1998
12. Resources In Science and Engineering Education. Cited 201: Available from http://www4.ncsu.edu/unity/lockers/users/f/felder/public/
13. Golter, P., Et Al., *Aligning Assessment,* American Society For Engineering Education, 2009
14. Golter, P., Van Wie, B., Windosr, J., Held, Gary., *Practical Considerations for MiniaturizedHands-On Learning Station.* American Society For Engineering Education, 2006, p. 3.
15. Chickering, A.W and Gamson, Z.F "Seven Principles for Good Practice in Undergraduate Education", The Wingspread Journal, Winona State University, (1984)
16. Abdul, B., Et Al. *Evaluation of Pedagogical Gains In a Fluid Flow Class When Using Desktop Learning Modules In An African University,* American Society For Engineering Education 2009.