AC 2012-3370: COLLABORATIVE RESEARCH: INTEGRATION OF CONCEPTUAL LEARNING THROUGHOUT THE CORE CHEMICAL ENGINEERING CURRICULUM YEAR 1

Dr. Milo Koretsky, Oregon State University

Milo Koretsky is a professor of chemical engineering at Oregon State University. He currently has research activity in areas related to thin film materials processing and engineering education. He is interested in integrating technology into effective educational practices and in promoting the use of higher level cognitive skills in engineering problem solving. Koretsky is a six-time Intel Faculty Fellow and has won awards for his work in engineering education at the university and national levels.

Dr. David L. Silverstein, University of Kentucky

David L. Silverstein is the PJC Engineering Professor of chemical engineering at the University of Kentucky. He is assigned to the College of Engineering's Extended Campus Programs in Paducah, Ky., where he has taught for 12 years. His Ph.D. and M.S. studies in Ch.E. were completed at Vanderbilt University, and his B.S.Ch.E. at the University of Alabama. Silverstein's research interests include conceptual learning tools and training, and he has particular interests in faculty development. He is the recipient of several ASEE awards, including the Fahein award for young faculty teaching and educational scholarship, the Cororan award for best article in the journal Chemical Engineering Education (twice), and the Martin award for best paper in the Ch.E. Division at the ASEE Annual Meeting.

Prof. John L. Falconer, University of Colorado, Boulder
Dr. Ronald L. Miller, Colorado School of Mines

Ronald L. Miller is professor of chemical engineering and Director of the Center for Engineering Education at the Colorado School of Mines, where he has taught chemical engineering and interdisciplinary courses and conducted engineering education research for the past 25 years. Miller has received three university-wide teaching awards and has held a Jenni teaching fellowship at CSM. He has received grant awards for education research from the National Science Foundation, the U.S. Department of Education FIPSE program, the National Endowment for the Humanities, and the Colorado Commission on Higher Education, and he has published widely in engineering education literature. His research interests include measuring and repairing engineering student misconceptions in thermal and transport science.

Collaborative Research: Integration of Conceptual Learning throughout the Core Chemical Engineering Curriculum – Year 1

Overview and Objectives

We report on the progress of the first year of a CCLI Type 2 project. The goal of this project is to create a community of learning within the discipline of chemical engineering (ChE) focused on concept-based instruction. The project plan is to develop and promote the use of a cyber-enabled infrastructure for conceptual questions, *the AIChE Concept Warehouse*, which ultimately could be used throughout the core ChE curriculum (Material and Energy Balances, Thermodynamics, Transport Phenomena, Kinetics and Reactor Design, and Materials Science). Conceptual questions, both as Concept Inventories and ConcepTests, will be available through an interactive website maintained through the Education Division of the American Institute of Chemical Engineers (AIChE), the discipline's major professional society. The overall objective is to lower the activation barrier for using conceptual instruction and assessment so that many more chemical engineering faculty will incorporate concept-based learning into their classes.

The specific objectives of this project are to:

1. Develop the AIChE Concept Warehouse, a flexible database-driven website for conceptual questions in the core chemical engineering sciences. Features of the AIChE Concept Warehouse include:
   a. Making concept questions available in different formats to facilitate widespread use.
   b. Allowing integration of questions within a course and from different courses so students can link concepts to one another and form a more cohesive cognitive structure.
   c. Populating the site with conceptual questions that are submitted and reviewed by faculty, and are catalogued, rated and linked for ease of use.

2. Develop and deliver workshops that explain and promote conceptual learning in Chemical Engineering.
   a. Present workshops at the ASEE Chemical Engineering Faculty Summer School, the Fall AIChE Annual Meeting, and the Summer ASEE Annual meeting.
   b. Present workshops to faculty and future faculty through department site visits.
   c. Assess the participant's perception of the workshops and follow up with faculty to determine the extent of curricular integration of concept questions.

Concept-based Learning tools

For approximately the last 20 years, the physics education research community has shown the effectiveness of concept-based learning tools in promoting learning. Two seminal works are particularly noteworthy. First, the Force Concept Inventory (FCI) provided an instrument to measure students' fundamental conceptual understanding of Newtonian mechanics.[1,2] The questions were designed to test a student's ability to apply the fundamental laws and principles in a way that does not require computation. Second, Eric Mazur published his book *Peer*

Instruction, which describes the use of *ConcepTests* to engage students in conceptual learning during lecture.[3] This structured questioning process actively involves all students in the class. Peer instruction encourages students to reflect on the problem, think through the arguments being developed, and put them into their own words. Just as important, it provides both student and instructor with feedback regarding student understanding of the concept.

Concept Inventories have emerged in many science and engineering fields.[4-16] Similarly numerous studies in physics, chemistry, and biology classrooms have shown that active learning pedagogies that are based on concept questions (*ConcepTests*) are more effective for student learning than traditional lecture.[17-27] This project intends to encourage and shift the focus of learning in chemical engineering classes by providing a resource of high quality *ConcepTests* and Concept Inventories for instructors to use.

Project Status

This poster will present the development status of the interactive AIChE Concept Warehouse software. The software structure is based on a synergy between a web-based user interface (programmed using PHP 5.3) and a commercial database (MySQL 5.1). Currently, the AIChE Concept Warehouse has 1,078 concept questions available for searching, viewing, and using in courses through the user interfaces. The student and instructor interfaces are available at http://cw.edudiv.org for the community, and university faculty can obtain an account through this site. In order to maximize compatibility with the current practices of potential adopters, we are designing the instructor interface to be familiar and user-friendly. The software allows interactive electronic use, as well as PowerPoint, Word, and pdf formats to be automatically generated so that conceptual learning and evaluation can be incorporated into instruction in various forms: in-class ConcepTests with student response (clickers, laptops, cell phones), concept inventories to evaluate student learning (or student preparation for a course), exam and homework problems.

A five-step design process is used to develop functions in the user interfaces. The steps include: (i) Developing a function list to be incorporated into the page; (ii) Creating a storyboard of a page that includes the listed section functions; (iii) Implementing the storyboard concept in a live webpage; (iv) Design team testing of live webpages and modification to enhance functionality and usability; and (v) External testing of live webpages and modification to enhance functionality and usability. More detail is provided elsewhere (ref)

Involvement of chemical engineering educators is crucial for the success of the *AIChE Concept Warehouse*. In order to foster community engagement, two types of activities have either started or are planned for the future. Special sessions and workshops have been presented as the ASEE Annual Conference and the AIChE Annual Meeting. Additionally, a 3-hour, two-part workshop at the ASEE Chemical Engineering Faculty Summer School in July, 2012. The project team is also available for independent department visits. If interested in hosting a department workshop, please contact the corresponding author. In general, the activities are intended to help faculty who are interested in incorporating educational methods and tools into their classrooms to encourage students to think more deeply about concepts central to chemical engineering.

If you would like to use the *AIChE Concept Warehouse*, the address is http://cw.edudiv.org

Acknowledgements

The authors gratefully acknowledge support from the National Science Foundation's Course, Curriculum and Laboratory Improvement Program, under the grants NSF 1023099, 1022957, 1022875, 1022785 "Collaborative Research: Integration of Conceptual Learning throughout the Core Chemical Engineering Curriculum." Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

1. Halloun, I. and Hestenes, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics* **53**, 1043.
2. Hestenes, David, Wells, Malcolm, and Swackhamer, Greg. (2002). Force Concept Inventory. *The Physics Teacher*, **30**,141.
3. Mazur, E. (1997) *Peer instruction*, Prentice Hall, Upper Saddle River, NJ.
4. Evans, D. L., Gray, G. L., Krause, S., Martin, J., Midkiff, C., Notaros, B. M., et al. (2003). Progress on concept inventory assessment tools. *Proceedings of the 33rd Annual ASEE/IEEE Frontiers in Engineering Conference,* Boulder, CO.
5. Rhoads, T. R., and Roedel, R. J. (1999). The wave concept inventory-a cognitive instrument based on Bloom's taxonomy. *Proceedings of the 29th Annual ASEE/IEEE Frontiers in Engineering Conference,* San Juan, PR.
6. Martin, J. K., Mitchell, J., and Newell, T. (2004). Work in progress: analysis of reliability of the fluid mechanics concept inventory. *Proceedings of the 34rd Annual ASEE/IEEE Frontiers in Engineering Conference,* Savannah, GA.
7. Jacobi, A., Martin, J., Mitchell, J., and Newell, T. (2003). A concept inventory for heat transfer. *Proceedings of the 33rd Annual ASEE/IEEE Frontiers in Engineering Conference*, Boulder, CO.
8. Krause, S., Decker, J. C., and Griffin, R. (2003). Using a materials concept inventory to assess conceptual gain in introductory materials engineering courses. *Proceedings of the 33rd Annual ASEE/IEEE Frontiers in Engineering Conference*, Boulder, CO.
9. Wage, K. E., Buck, J. R., Wright, C. H. G., and Welch, T. B. (2005). The Signals and Systems Concept Inventory. *IEEE Transactions on Education* **48**, 448.
10. Steif, P. S., and Dantzler, J. A. (2005). A Statics Concept Inventory: Development and Psychometric Analysis. *Journal of Engineering Education*, **94,** 363.
11. Stone, A. D. 2006. A Psychometric Analysis of the Statistics Concept Inventory. Ph. D. dissertation, University of Oklahoma.
12. Richardson, J., Steif, P., Morgan, J., and Dantzler, J. (2003). Development of a concept inventory for strength of materials. *Proceedings of the 33rd Annual ASEE/IEEE Frontiers in Engineering Conference,* Boulder, CO.
13. Midkiff, K. C., Litzinger, T. A., and Evans, D. L. 2001. Development of Engineering Thermodynamics Concept Inventory instruments. *Proceedings of the 31st Annual ASEE/IEEE Frontiers in Engineering Conference,* Reno, NV.
14. Santiago Román, A. I. (2009). Fitting Cognitive Diagnostic Assessment to the Content Assessment Tool for Statics. PhD dissertation, Purdue University, West Lafayette, IN.
15. Streveler, R.A., Olds., B.M., Miller, R.L., and Nelson, M.A. (2003). Using a Delphi Study to Identify the Most Difficult Concepts for Students to Master in Thermal and Transport Science. *Proceedings of the American Society for Engineering Education Annual Conference* (electronic), Nashville, Tennessee.
16. Streveler, R. A., Litzinger, T. A., Miller, R. L., and Steif, P. S. (2008). Learning conceptual knowledge in engineering: Overview and future research directions. *Journal of Engineering Education* **97**, 279.
17. Streveler, R.A., Miller, R.L., Santiago Roman, A.I, Nelson, M.A., Geist, M.R. and Olds, B.M. (2010). A rigorous methodology for concept inventory development: using the assessment triangle to develop and test the thermal and transport concept inventory (TTCI). *International Journal of Engineering Education*, in press.
18. Downing, S. M. (2006). Twelve steps for effective test development. In *Handbook of test development*, edited by Downing, S. M. and T. M. Haladyna, 3-26. Mahwah, NJ: Erlbaum.

19. Caldwell, J. E. (2007). Clickers in the Large Classroom: Current Research and Best-Practice Tips. *CBE Life Sci Educ*, **6**, 9.
20. Crouch, C.H. and Mazur, E. (2001) Peer Instruction: Ten Years of Experience and Results. *American Journal of Physics*, **69**, 970.
21. Duncan, D. *Clickers in the Classroom*, Addison Wesley, San Francisco (2005).
22. MacArthur, J. R and Jones, L. L. (2008). A review of literature reports of clickers applicable to college chemistry classrooms, *Chem. Educ. Res. Pract.*, **9**, 187.
23. Smith, M.K., Wood, W.B. Adams, W.K. Wieman, C. Knight, J.K. Guild, N. and Su, T.T. (2009). Why Peer Discussion Improves Student Performance on In-Class Concept Questions. *Science*, 323, 122-124.
24. McDermott, L.C. (2001). Oersted Medal Lecture 2001: Physics Education Research-The Key to Student Learning", *American Journal of Physics*, **69**, 1127.
25. Falconer, J.L. (2004). Use of ConcepTests and Instant Feedback in Thermodynamics. *Chemical Engineering Education*, **38**, 64.
26. Falconer, J.L. (2007). Conceptests for a Chemical Engineering Thermodynamics Course. *Chemical Engineering Education*, **41**, 107.
27. Brooks B.J., and Koretsky, M.D. (2011). The Influence of Group Discussion on Students' Responses and Confidence during Peer Instruction. *J. Chem. Educ.*