Cooperative Learning: Lessons and Insights from Thirty Years of Championing a Research-Based Innovative Practice

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Abstract - **Innovation according to Denning and Dunham (2010) is "the adoption of a new practice in a community." I argue that our innovations need to be based on good learning theory and good instructional practice. The Johnson and Johnson conceptual model of cooperative learning is an excellent example of a widely adopted evidence-based practice. I identified cooperative learning as important for engineering education in about 1974, tried it in my classes and did some systematic research on it with David and Roger Johnson, introduced it to the engineering education community in 1981 (FIE conference and JEE paper), and it took over 25 years for it to become widespread practice. My point in presenting this story is I don't think we can afford to wait 25 or more years for the current innovations to make it into practice. This paper summarizes the history of the emergence of cooperative learning in engineering education; documents the development of the theoretical, empirical, and practical support; maps the milestones and lessons learned; and provides insights and guidance for engineering education researchers and innovators especially concerning increasing the rate of adoption of evidence-based promising practices.**

Index Terms – cooperative learning, evidence-based promising practice, engineering education research and innovation

CLARIFICATION

Since there is the possibility of a confusion of terms, I'm starting with the definition of cooperative learning and highlighting how it is different from collaborative learning and cooperative education (or co-op). [Note: Thanks to the anonymous reviewer who recommended this addition]

Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each others' learning (Johnson and Johnson, 1974; Smith, Johnson and Johnson, 1981; Johnson, Johnson and Smith, 1991). Carefully structured cooperative learning involves people working in teams to accomplish a common goal, under conditions that involve both positive interdependence (all members must cooperate to complete the task) and individual and group accountability (each member individually as well as all members collectively accountable for the work of the group).

A common question is, "What is the difference between cooperative and collaborative learning?" Both pedagogies are aimed at "marshalling peer group influence to focus on intellectual and substantive concerns" (Matthews, et.al, 1995). The principal difference is that cooperative learning requires carefully structured individual accountability, whereas collaborative learning does not. Oxford (1997) summarizes the differences as follows, "Cooperative learning refers to a particular set of classroom techniques that foster learner interdependence as a route to cognitive and social development. Collaborative learning has a "social constructivist" philosophical base, which views learning as construction of knowledge within a social context and which therefore encourages acculturation of individuals into a learning community."

Another potential source of confusion is cooperative education (or co-op), which is "is a structured method of combining classroom-based education with practical work experience. A cooperative education experience, commonly known as a "co-op", provides academic credit for structured job experience" (Auld, 1972).

HISTORY

[Note: History and Concurrent Developments sections were adapted from Smith (2010)]
My first encounter with cooperative learning occurred in about 1974 in a Social Psychology of Education course taught by one of David Johnson's PhD students, Dennis Falk who is currently a Professor of Social Work at the University of Minnesota – Duluth. I began taking courses in the College of Education in the early 70s because I had an overwhelming sense that there was a better way to help engineering students learn than what I was doing, which was essentially what had been done to me, that is, lecture, homework assignments and individual exams. This overwhelming sense of a better way of doing things was prompted by questions the students asked, which revealed that they had no idea what I was talking about. A representative setting was a course in thermodynamics and kinetics – very abstract areas involving a lot of mathematics – where I was "teaching as taught." My sense that there was a better way was grounded in my training and experience as an engineer, where one of the fundamental ideas is "advancing the state-of-the-art". What I encountered in the

Social Psychology of Education course, however, changed my life.

During the first session, Professor Falk assigned us to groups, which was a bit of a surprise to me as I don't think I had ever experienced this before. He said that there was a lot of dense content and many difficult concepts in the course, and that some of us could probably manage by ourselves but most would benefit from interacting with others. He stressed the ideas of interdependence and accountability, and modeled them through a series of group exercises and assignments. The emphasis on interdependence and accountability was a revelation for me, since it was familiar. This was the way I worked as an engineer on the job and in my research setting. Interdependence and accountability were central to success! At that moment I thought, "Why don't we do this in engineering classes?" The rest, some will say, is history as cooperative learning is now embraced by many engineering faculty and its use is increasing by faculty at large as indicated by the UCLA Higher Education Research Institute Survey of Faculty as shown in Table 1 (DeAngelo and others, 2009).

Table 1. The American College Teacher: National Norms for 2007-2008

Methods Used in "All" or "Most" Classes	All Faculty 2005 - %	All Faculty 2008 - %	Assistant – 2008 - %
Cooperative Learning	48	59	66
Group Projects	33	36	61
Grading on a curve	19	17	14
Term/research papers	35	44	47

Cooperative learning was introduced nationally to engineering educators at the 1981 Frontiers in Education Conference in Rapid City, SD (Smith, Johnson, Johnson, 1981a); a little over 30 years after Morton Deutsch's pivotal article (Deustch, 1949). The 1981 paper was based on David and Roger Johnson's pioneering work (Johnson & Johnson, 1974) as identified by Karl Smith in the mid-1970s as a promising practice for engineering education. Also in 1981 an article, "Structuring learning goals to meet the goals of engineering education," (Smith, Johnson & Johnson, 1981b) was published in the *Journal of Engineering Education*.

The 90s saw terrific growth in the number of books and articles on cooperative learning and the number of practitioners. David and Roger Johnson and Karl Smith published two books in 1991 (Johnson, Johnson & Smith, 1991a, 1991b) – a research oriented report: Cooperative learning: Increasing college faculty instructional productivity, and a resource guide for faculty: Active learning: Cooperation in the college classroom – which has helped many faculty implement cooperative learning.

There are currently over 400 articles on cooperative learning in science, math, engineering, and technology disciplines, and several of these have been included in meta-analyses (Smith, Sheppard, Johnson and Johnson, 2005; Johnson, Johnson and Smith, 2007). In 1997 three researchers at the University of Wisconsin, Madison completed a meta-analysis of the research on cooperative learning in college-level one science, mathematics, engineering, and technology (Springer, Stanne & Donovan, 1997). Mean effect sizes for achievement, persistence, and attitudes were 0.51, 0.46, and 0.55, respectively. Springer, et.al., state "The 0.51 effect of small-group learning on achievement reported in this study would move a student from the 50 percentile to the 70 on a standardized test. Similarly, a 0.46 effect on the students' persistence is enough to reduce attrition in SMET courses and programs by 22%." The study was published in the *Review of Educational Research* (Springer, Stanne and Donovan, 1999).

CONCURRENT DEVELOPMENTS

The National Institute of Education report, *Involvement in Learning: Revitalizing Involvement in Learning: Realizing the Potential of American Higher Education. Final Report of the Study Group on the Conditions of Excellence in American Higher Education* was published in 1984 as was Astin's (1984) "Student Involvement" article. The congruence of support for cooperative learning provided by this work on the importance of student involvement in learning strengthened my resolve to focus in this area, and I think helped build the foundation of support that influenced the broader community.

A couple of the *New Directions for Teaching and Learning* volumes, 32 and 81, focused on large classes, and included several chapters emphasizing the social basis of learning. Examples include Frederick's (1987) article "Student Involvement: Active Learning in Large Classes," and Cooper and Robinson's (2000) article "The Argument for Making Large Classes Seem Small." Teaching large classes well is an ongoing challenge for college and university faculty and many books and articles have been written to help faculty, such as Stanley and Porter (2002).

The late 80s and early 90s was a landmark period for supporting and advancing cooperative learning. In 1987 the "Seven Principles for Good Practice in Undergraduate Education" was published in the *AAHE Bulletin* (Chickering and Gamson, 1987). Three of the seven principles emphasized the importance of interaction: Good Practice Encourages Student-Faculty Contact, Good Practice Encourages Cooperation Among Students, and Good Practice Encourages Active Learning. Chickering and Gamson followed up on the *AAHE Bulletin* article in volume 47 (1991), *Applying the Seven Principles for Good Practice in Undergraduate Education*. Gamson (1991) noted in her history of the Seven Principles that more than 150,000 copies were ordered directly from the Johnson Foundation and, since it wasn't copyrighted, an unknown (and likely very large) number of copies were distributed electronically. The publication of the "Seven Principles for Good Practice

in Undergraduate Education" was a marker event and provided enormous support for the change from competitive and individualistic learning to cooperative learning.

Several research studies supporting the social basis of learning were published during this period. Pascarella and Terenzini (1991) wrote in their synthesis of research of how college affects students, "Perhaps the strongest conclusion that can be made is the least surprising. Simply put, the greater the student's involvement or engagement in academic work or in the academic experience of college, the greater his or her level of knowledge acquisition and general cognitive development… If the level of involvement were totally determined by individual student motivation, interest, and ability, the above conclusion would be uninteresting as well as unsurprising. However, a substantial amount of evidence indicates that there are instructional and programmatic interventions that not only increase a student's active engagement in learning and academic work but also enhance knowledge acquisition and some dimensions of both cognitive and psychosocial change."

Research using a variety of theoretical frameworks and methodologies supported the claim that the frequency and quality of student-student and student-faculty interaction are most influential for college student's academic development, personal development and satisfaction (Astin, 1993; Light, 1992; Johnson, Johnson & Smith, 1991b). Astin's (1993) large-scale correlational study of what matters in college (involving 27,064 students at 309 baccalaureate-granting institutions) found that two environmental factors were by far the most predictive of positive change in college students' academic development, personal development, and satisfaction. These two factors—interaction among students and interaction between faculty and students—carried by far the largest weights and affected more general education outcomes than any other environmental variables studied, including the curriculum content factors. This result indicates that how students approach their general education and how the faculty actually deliver the curriculum is more important than the formal curriculum, that is, the content, collection, and sequence of courses. The assessment study by Light (1992) of Harvard students indicates that one of the crucial factors in the educational development of the undergraduate is the degree to which the student is actively engaged or involved in the undergraduate experience. Johnson, Johnson and Smith (1991) summarized meta-analysis results for randomized design field and laboratory studies of cooperative, competitive and individualistic learning and reported significant effect sizes for cooperative learning for academic success, quality of relationships, and psychological adjustment. Several follow up reports have provided further support for cooperative learning (Johnson, Johnson and Smith, 1998, 2007; Smith, Sheppard, Johnson and Johnson, 2005; Springer, Stanne and Donovan, 1999).

EMBRACING EVIDENCE-BASED PROMISING PRACTICES

Fairweather (2008) argues in his summary report, "Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education" for a National Research Council workshop, "… although faculty in STEM disciplines vary substantially on a broad array of attitudinal and behavioral measures (Fairweather & Paulson, 2008) careful reviews of the substantial literature on college teaching and learning suggest that the pedagogical strategies most effective in enhancing student learning outcomes are not discipline dependent (Pascarella and Terenzini, 2005). Instead, active and collaborative instruction coupled with various means to encourage student engagement invariably lead to better student learning outcomes irrespective of academic discipline (Kuh et al., 2005, 2007). The assumption that pedagogical effectiveness is disciplinary-specific can result in "reinventing the wheel," proving yet again that pedagogies engaging students lead to better learning outcomes (p. 4-5)."

Svinicki wrote in *New Directions for Teaching and Learning (NDTL),* volume 42 (1990, page 1), "There is a real need for 'translators and disseminators' whose job it is to extract the best from the array of potential ideas and pass it along in workable form to individual faculty members," and I think this will continue to be an crucial need and a role that *NDTL* will help fulfill. Furthermore, more engineering education researchers and innovators need to focus on transforming current practice. The challenges are great, however, as Fairweather (2008) argues, "Finally, resistance to adopting more effective teaching strategies in part derives from the perception of STEM faculty that the teaching process is at odds with the research process, and that research is more interesting and more valued at their institutions (Fairweather 1996; Massy, Wilger, & Colbeck 1994). The perception of the importance of teaching in faculty rewards and the perceived consequence of spending more time on improving teaching, namely having less time for research, adversely affects faculty involvement in pedagogical reform (Fairweather 2005). This behavioral pattern holds true even when faculty members express a deep commitment to teaching and to their students (Leslie, 2002)."

ADVANCING THE PRACTICE AND CLOSING THE LOOP

The foundational work and the extent of adoption and adaption of the work on student engagement can be strengthened. Chickering and Gamson (1987) "Best Practices" is widely cited and their Wingspread gathering and report was pivotal; however, as noted by Fairweather (2008) there is a large amount of compelling evidence for active student engagement (Astin, 1984, 1993; Light, 1992; Pascarella & Terenzini, 1991, 2008; Kuh, et.al., 2005; Kuh, 2008; Johnson, Johnson & Smith, 1991, 1998, 2007; Smith, Sheppard, Johnson & Johnson, 2005; Smith, Clarke-Douglas & Cox, 2009).

Based on the data in Table 1 is seems safe to assume that cooperative learning (or something like it or based on it) has been embraced by higher education faculty. BTW: There is a plethora of cooperative- learning-based spin offs – Peer Instruction, Just-In-Time-Teaching (JITT), Peer Led Team Learning (PLTL), Process Guided Inquiry Learning (POGIL), etc. and a couple models that have deeply embraced the conceptual cooperative learning model – SCALE-UP and the University of Delaware PBL approach (Beichner, 2006; Beichner, et.al. In Press; Allen, Duch and Groh, 1996). It might be interesting to investigate how and why these ideas were embraced by higher education faculty.

The question of change in STEM undergraduate education is currently front and center. Wieman, Perkins and Gilbert's *Change* article, "Transforming science education at large research universities," which was published about a year ago advocate a science education incentives change model. Currently Carl Wieman is Associate Director for Science, White House Office of Science and Technology Policy (OSTP) and his talk at the NSF CCLI/TUES PI meeting in January stressed "thinking like a scientist/engineer" to achieve better learning and, especially, measuring impact. Myles Boylan noted in his presentation "The Federal Environment for STEM Education Programs: Implications for TUES" that OSTP is actively involved in the evaluation of STEM Ed programs at NSF and that OMB is also taking a detailed interest. Boylan summarized NSF Responses (New Emphases), which included redesign of CCLI to TUES, noting that innovation equals transformative research and education, and renewed concern about sustainability of projects.

The National Academy of Engineering Center for the Advancement of Scholarship on Engineering Education hosted the conference "Characterizing the Impact and Diffusion of Engineering Education Innovations Forum" in February, 2011, and several commissioned papers address innovation in engineering education (http://www.nae.edu/Activities/Projects20676/CASEE/2633 8/26183/26293.aspx)

The Scholarship of Teaching and Learning (SoTL) is receiving increased attention in higher education and many faculty are embracing more scholarly approaches to teaching and learning. Streveler, Borrego and Smith (2007) augmented the levels of inquiry from the Hutchins and Shulman (1999) as shown in Figure 1.

Levels 1, 2 & 3 were articulated by Hutchings and Shulman (1999), Level 0 was added by Jack Lohmann, and Level 4 was added by Streveler, Borrego and Smith (2007). Faculty who practice engineering education should work at Level 2 or above as noted by Wankat (et.al., 2002) and also by Coppola (2011). A few diehards will practice at Level 0 or 1 and the proportion needs to continually reduce. Faculty practicing at Levels 4 will likely be a small fraction of the

Levels of inquiry in engineering education

- **Level 0** Teacher
  - Teach as taught ("distal pedagogy")
- **Level 1** Effective Teacher
  - Teach using accepted teaching theories and practices
- **Level 2** Scholarly Teacher
  - Assesses performance and makes improvements
- **Level 3** Scholar of Teaching and Learning
  - Engages in educational experimentation, shares results
- **Level 4** Engineering Education Researcher
  - Conducts educational research, publishes archival papers

Source: Streveler, R., Borrego, M. and Smith, K.A. 2007. Moving from the "Scholarship of Teaching and Learning" to "Educational Research:" An Example from Engineering. *Improve the Academy,* Vol. 25, 139-149.

Figure 1 Levels of Inquiry

entire community; however, those practicing at Level 3 could be a large portion of the community.

An overriding goal for continuing work is assisting faculty in increasing the extent to which they take a scholarly approach to teaching and learning or envision a developmental or advancement process, such as advancing along the levels of inquiry.

Two additional ideas to increase the extent of adoption of engineering approaches in engineering education are through embracing the

1. Integration and alignment of content (or curriculum), assessment, and pedagogy (or instructional strategy) for learning module, course, and program design – engineering approach of developing requirements or specifications, assigning relevant metrics, and preparing prototypes that meet the requirements, and
2. Cycle of improvement – Closing the loop between research and practice – see Figure 2 for example from Myles Boylan (2011) presentation at the NSF CCLI/TUES PI meeting and Figure 3 from example from Jamieson and Lohmann (2009) report on engineering education.

The argument for the alignment of content, assessment and pedagogy has been articulated and elaborated on by numerous researchers (Fink, 2003; Pellegrino, 2006; Wiggins and McTighe, 1998, 2005). Pedagogical approaches – cooperative learning; problem-based, project-based, case-based learning, and so forth – need to be well integrated with the content (especially the intended learning outcomes), and both of these elements must be aligned with the assessment. Cooperative learning is particularly important for those student learning outcomes that involve teamwork, and especially those that involve the mastery of complex concepts and procedures.

My colleagues and I are working to help engineering education PhD students as well as faculty around the world implement an integrated engineering design approach to courses and programs (Streveler and Smith, 2010; Streveler, Smith and Pilotte, 2011, 2012). Felder and Brent (2003) are also working to help faculty design more effective instruction.

Our Purdue Engineering Education foundation PhD course, Content, Assessment and Pedagogy: An Integrated Engineering Design Approach is based on learning sciences research and post-secondary learning theory (Ambrose, et.al, 2010; Svinicki, 2004) and the design of instruction. The course participants find Perkins' (2009) *Making learning whole: How seven principles of teaching can transform education* particularly helpful. Briefly, Perkins' advocates that designers:

1. Engage some version of holistic activity, not just bits and pieces
2. Make the activity worth learning
3. Work on the hard parts
4. Explore different versions of and settings for the activity.

Perkins' down-to-earth language and fascinating examples help students master and implement these challenging ideas in their courses.

I began this reflection with a story about the connection I made between my experience in the Social Psychology of Education course (where I first experienced cooperative learning) and my work as an engineering practitioner and researcher. Looking back I would argue that I helped close the loop between a problem or opportunity in practice and an evidence-based instructional practice. Closing the loop between educational practice and research, and especially focusing on innovation in engineering education is gaining in prominence and urgency as noted by Boylan (2011) and Jamieson and Lohmann (2009). I am hopeful that the reflections, ideas, and resources in this paper will help the next generation close loops and especially reduce the cycle time.

CONCLUSIONS AND RECOMMENDATIONS

I'd like to close with a little personal history, and my take on the current sense of urgency. About eight years ago at a Center for the Advancement of Engineering Education (CAEE) Advisory Board meeting Elaine Seymour asked the question, "What is your theory of change?" She claimed later that she was looking for a brief answer; however, my colleagues and I dug deeply into the change literature and wrote a paper titled Engineering change (Smith, et.al, 2004). We primarily emphasized models of change and argued that there are so many competing ideas that an accepted

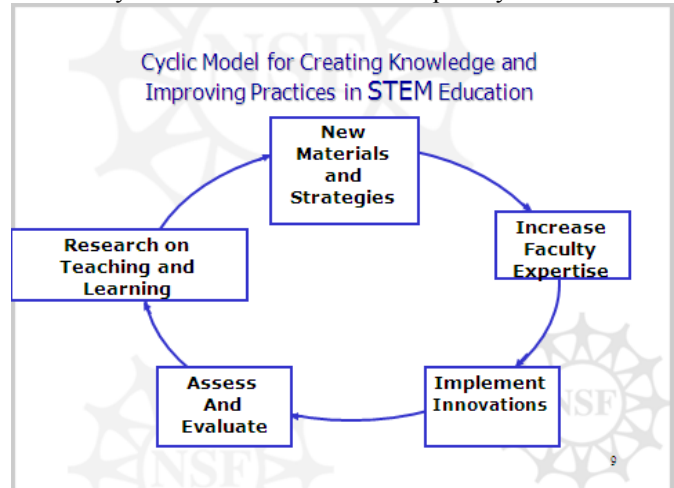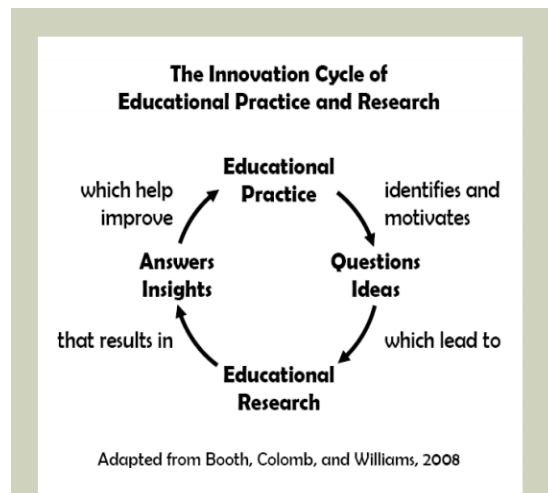theoretical framework hasn't been developed. As a community of researchers I think we implicitly embraced the

Figure 2 Cyclic Model for Creating Knowledge and Improving Practices in STEM Education (Boylan, 2011)

Figure 3 Innovation Cycle of Educational Practice and Research (Jamieson/Lohmann, 2009)

notion that our role was to do world class research and the results would change or at least influence practice (and I think Elaine was trying to get us to question that assumption). The final report for the CAEE project was published recently and it contains the results of one of the largest-scale systematic studies of engineering education ever done. (Atman, et.al. 2010).

As stressed earlier, change in engineering education has reached new heights of urgency. We argue in an FIE mini-workshop for integration and alignment of content (or curriculum), assessment, and pedagogy (or instruction) for learning module, course, and program design and provide some essential methods for designing courses and curricula in this way (Streveler, Smith and Pilotte, 2011). Our workshop framing is an engineering design approach, that is to say, it begins with requirements or specifications, emphasizes metrics, and then evolves into preparation of prototypes that meet the requirements. I think the widespread adoption of these integrated engineering education design approaches is critical for advancing engineering education innovation.

The more we embrace engineering approaches the more likely we will see substantive changes in engineering education as well better prepare graduates with the knowledge, skills, and habits of mind needed for engineering practice.

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