Preparing the Next Generation of Engineering Educators and Researchers: Cooperative Learning in the Purdue University School of Engineering Education PhD Program[1]

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Cooperative learning has been part of the landscape of engineering education for almost 30 years. The conceptual cooperative learning model was introduced to the engineering education community in 1981 (Smith, Johnson, & Johnson, 1981a; Smith, Johnson, & Johnson, 1981b) and was continually refined and elaborated for engineering educators (Felder, 1995; Prince, 2004; Smith, 1995; Smith, Sheppard, Johnson, & Johnson, 2005) and higher education faculty in general (Johnson, Johnson, & Smith, 1991; Johnson, Johnson, & Smith, 1998; Johnson, Johnson, & Smith, 2000, 2006, 2007; MacGregor, Cooper, Smith, & Robinson, 2000; Millis & Cottell, 1998; Smith, 1996, 1998; Smith, Cox, & Douglas, 2008). The influence of foundational work on cooperative learning can be seen in the University of Delaware Problem Based Learning model (Allen, Duch, & Groh, 1996 ; Duch, Groh, & Allen, 2001), the SCALE-UP model at North Carolina State (Beichner, Saul, Allain, Deardorff, & Abbot, 2000), the Technology Enhanced Active Learning (TEAL) model (Dori & Belcher, 2005; Dori et al., 2003), as well as many others.

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Cooperative learning as well as other forms of active student engagement has received lots of attention in undergraduate STEM (Science, Technology, Engineering, & Mathematics) programs. Because these approaches are less common in graduate programs in engineering and other STEM disciplines, we saw this volume as an opportunity for a unique contribution.

Numerous studies and reports claim that a different type of engineering graduate is needed, one with a much broader range of professional skills in addition to the widely sought technical skills. The principal question addressed in this chapter is "Can we increase the rate of development of the theory and practice needed to prepare engineering graduates for 21st century opportunities and challenges through the use of cooperative learning strategies such as constructive controversy?" The context is an engineering education PhD course, History and Philosophy of Engineering Education, in the School of Engineering Education (ENE), College of Engineering, Purdue University. We used the instructional strategy of constructive academic controversy, a formal cooperative learning strategy.

Background, Context, and Urgency

A growing number of national reports argue that a different type of engineer is needed to practice effectively in the 21st Century (Duderstadt, 2008; Galloway, 2007; Lynn & Salzman, 2006; Lynn & Salzman, 2007; NAE, 2004, 2005; Redish & Smith, 2008). These reports also emphasize that the approach to preparing these students needs to be different, i.e., better matched to developing the knowledge, skills, and habits of mind or modes of thinking that will be required. For example, engineers in practice must be skillful at representing and managing trade-offs, such as this one: thicker metal in automobiles makes them safer (they can absorb more energy in a crash) versus thinner meta, which makes the automobile more fuel efficient (lighter weight). This specific example focuses on trade-offs at a technical level. Many of the decisions facing engineers involve multiple perspectives, including not only technical, but also social, economic, environmental, global, and so forth; and the trade-offs are therefore more complex and difficult to represent and manage. Effectively managing trade-offs requires that engineers understand multiple perspectives and make persuasive and compelling arguments based on evidence.

We claim that modeling and coaching graduate students in the use of cooperative learning will better prepare future faculty and researchers for educating the new engineer. Also, the Engineering Education (ENE) PhD students learn a mode of inquiry that will help them craft compelling arguments and assist them in becoming effective researchers.

The engineering education PhD program at Purdue is a competency-based program focused on (1) developing engineering education research practitioners and (2) modeling, coaching and preparing ENE PhD students to use modern empirically and theoretically grounded pedagogical practices (such as the conceptual cooperative learning model).

Several courses within the School of Engineering Education at Purdue focus on an argument-claim-evidence-method model (Booth, Colomb, & Williams, 2008; Lunsford, Ruszkiewicz, & Walters, 2004), including three foundation courses: Engineering Education Inquiry, History and Philosophy of Engineering Education, and Content, Assessment, and Pedagogy. These courses—as well as most courses in the program—use aspects of cooperative learning, including think-pair-share, cooperative jigsaw, cooperative projects, and constructive controversy. The key elements of well-structured cooperative learning—positive interdependence, individual and group accountability, promotive interaction, teamwork skills, and group processing—are emphasized (Johnson, Johnson, & Smith, 2006).

History and Philosophy of Engineering Education

The specific course selected for this chapter is History and Philosophy of Engineering Education. This course was selected for a variety of reasons: (1) it is a new course and the instructors tried to be as transparent as possible with the students in the course development process with an emphasis on learning pedagogy, and not just content; and (2) the course featured the constructive controversy formal cooperative learning strategy. History and Philosophy of Engineering Education is one of six core courses taken by engineering education PhD students within Purdue's School of Engineering Education.

We put a lot of effort into planning the course. Like Robinson & Cooper and Cohen (this volume), we believe in a mastery oriented classroom where outcomes are identified, modeled by faculty and practiced by students with peer and faculty feedback. The student learning outcomes for the course were:

1. Understand the history of engineering education and how that shapes our collective role as constructor of participant in this emerging field (Felder, Sheppard, & Smith, 2005; Steering Committee, 2006)
2. Critically describe the forces influencing past, present, and future scenarios of engineering education
3. Describe how personal past experiences within engineering connect with future roles in engineering education
4. Develop and articulate a personal philosophy on engineering education
5. Construct arguments about the similarities and differences between the constructs of engineering, science, art and design
6. Participate in a "community of practice" culture through formation of our own community and participation in the broader community of engineering education

7. Use reflection as a tool of self-discovery for shaping and refining personal philosophies
8. Articulate personal perspectives on foundational topics within engineering education by engaging in and leading thoughtful and critical discussions.

Three themes were repeated throughout the course: What is engineering? Who gets to be an engineer? and Who decides? We encouraged students to keep these questions in mind as they read the course materials as well as during their discussions and writing. Assessment feedback at the end of the semester indicated that the objectives were met, and we still hear students echoing the three theme questions more than a semester later.

The class met twice per week for 75 minutes over a 15-week semester. Eight students were enrolled in the course, including five women and three men. The normal flow for the class included assigned readings for each class period. We expected the students to complete the readings prior to class and to come to class prepared to engage in discussion or a discussion-based activity.

Constructive Controversy

Constructive controversy is a good pedagogical choice for the course because of the link between forming and articulating good arguments—claim-reason-evidence—and the format of the constructive controversy approach, which provides students with structure and practice in providing evidence and rationale to support their position. The specific application had the following features:

1. Students had the opportunity to craft arguments with a partner and verbally try out the claim:
    - Students' short arguments must be laden with reasons and evidence
    - Students have opportunities to reshape arguments during conversation

- Students actively see the importance of evidence in convincing peers of their position
- Students also have the opportunity to argue for other positions, which helps them see what evidence is needed to change their own minds

2. Students examine a question such as: “What is engineering?” by analyzing people actually doing design work
3. Students have the opportunity to grapple with the importance of representing and managing trade-offs in engineering and to practice arguing from evidence.

Constructive Academic Controversy

Constructive academic controversy (sometimes referred to as structured controversy) is a formal cooperative learning approach that emerged from the Johnson & Johnson cooperative learning group at University of Minnesota in the late 70’s and early 80’s. The approach has been studied extensively and has excellent theoretical, empirical and practical support (Johnson & Johnson, 1987, 2007; Johnson, Johnson, & Smith, 1997; Johnson, Johnson & Smith, 2000). Structured controversy was introduced to the engineering education community in the 1980s (Smith, 1984), and although it was received with some interest, this approach didn’t resonate with the community as much as cooperative project-based or problem-based learning did.

Re-engaging students and faculty with constructive controversy is important and timely for numerous reasons, including Daniel Pink’s (2005; 2006) argument about our current era, the importance of mastery learning, and the role of complexity in decision making.

Pink claims in his book, *A Whole New Mind*, and DVD, that we are moving from the knowledge age to the conceptual age. He argues that artists and empathizers will rule. Pink emphasizes the importance of the ‘right brain’ senses, particularly the idea of empathy (perspective taking), symphony (connecting many ideas together), story (the ability to develop an argument rather than relay facts), meaning (developing a greater understanding of the issues within context) and play (to a certain extent, the open discussion and flow of ideas can be seen as a form of play through language), and design (in designing an argument and then a counter argument). Pink's ideas get at the heart of the kinds of thinking and the essential attributes—creativity and empathy—needed by future engineers.

Peter Block (2002) makes similar arguments and offers a creative synthesis. Block argues that a synthesis is needed among the engineer, economist, and artist archetypes. He suggests that the architect provides an image that integrates the polarized worlds of the engineer-economist and the artist. Furthermore, he notes that the "task of the social architect is to design and bring into being organizations that serve both the marketplace and the soul of the people who work within them" (p. 171).

Constructive controversy is aligned with promoting an environment with a mastery learning orientation, since each group has a cooperative goal of ensuring that all members understand and are able to articulate the best arguments on all sides. This is similar to Robinson & Cooper's (this volume) goal of using discussion to strengthen understanding through explanation. In a mastery-oriented environment, learning is of primary importance over end performance. Academic constructive controversy is not about winning or losing the argument, or even who has the best argument; it is about finding the best solution that is agreeable to all participants. Learning environments can influence the learner's approach (Pintrich, Marx, & Boyle, 1993). Mastery learning orientations promote deeper understanding and greater self-regulated learning (Dweck & Leggett, 1988; Pintrich & De Groot, 1990; Pintrich et al., 1993).

Complexity and complex adaptive systems researchers provide lots of evidence for the difficulty of prediction in complex settings (Axelrod & Cohen, 2001; Miller & Page, 2007). Page (2007) provides detailed support for the claim, “Diverse perspectives and tools enable collections of people to find more and better solutions and contribute to overall productivity” (p. 13). The importance of articulating and representing diverse perspectives is another central feature of the constructive academic controversy model.

We have presented what we believe is a compelling argument for using constructive controversy:

- National reports call for change in the way we educate our students so timing is right
- Constructive controversy is in line with best teaching practices related to active and mastery-oriented learning and new ways of thinking about knowledge and knowing
- Constructive controversy promotes the types of skills we want future engineers to have.

This argument prompted our own use of constructive controversy, and we believe the outcomes support the argument. The details of our use of constructive academic controversy in the History and Philosophy of Engineering Education PhD course are summarized in the next section.

Implementation of Constructive Controversy in History and Philosophy of Engineering Education

Although we tried to integrate constructive academic controversy throughout the course, one specific session that worked well was assigning viewing perspectives for a video of engineers at work. Like Robinson & Cooper and Cottell (this volume), we believe that clarity of assignment is critical and therefore put effort into introducing and guiding the activity so that our expectations were clear.

In the class period prior to conducting the constructive controversy, students received a brief overview of the activity and a reading assignment by Rowland (2004) describing a philosophy of engineering. Based on previous activities, we found that students tended to be more mentally and emotionally prepared to engage in class if they know what will be expected of them; part of setting expectations for student responsibility for learning also mentioned by Panitz and Cohen (this volume). It is also helpful if they understand how assigned readings will connect to those class activities. We explained to students that the activity would involve thinking about ways design is represented and that Rowland's article "*Shall we dance? A design epistemology for organizational learning and performance*" would help them think creatively and get into the space of thinking about philosophy of engineering.

Our overview of the procedure was based on an assigned reading (Johnson et al., 2000), and we used a set of PowerPoint slides developed by Smith and Matusovich to guide the students. The slides are posted to www.ce.umn.edu/~smith/links.html (scroll down to presentations). Several students had experienced this approach in prior courses, such as Leadership, Policy and Change (another ENE foundation course). Three factors made this activity easy to facilitate: (1) some of the students had prior experience with structured controversy; (2) most students were familiar with cooperative learning: and, (3) the students generally wanted to learn to use best teaching practices. Similar to the novice geology students described by Nuhfer (this volume), ENE graduate students are often used to the large lecture style courses they experienced as undergraduate engineering students. Unlike Nuhfer's geology students, the ENE graduate students are also very often people who see faults in how they were educated and want to make changes for coming generations of engineers.Where students are less familiar with cooperative learning practices, content appropriate exercises similar to Nuhfer's (this volume) *Unique Earth Brainstorming Posters* or Panitz's (this volume) pre-semester letter introducing cooperative learning might help facilitate the transition to cooperative learning activities.

We introduced constructive controversy with the following paraphrased quote from Helen and Alexander Astin (Astin & Astin, 1996):

> **Controversy with Civility—**recognize that differences of viewpoint are inevitable and that such differences must be aired openly but with civility. Civility implies respect for others, a willingness to hear about each other's viewpoints, and the exercise of restraint in criticizing the views and actions of others. Controversy can often lead to new, creative solutions to problems, especially when it occurs in an atmosphere of civility, collaboration, and common purpose. (p. 59)

On the day of the activity, we had approximately 75 minutes to introduce, complete and reflect on the academic constructive controversy activity. The overall plan for the class session was:

1. Brief introduction to constructive controversy as an activity and as a teaching tool
2. Details on mechanics of activity
3. Assign pairs
4. Watch video
5. Constructive controversy discussion with their partner
6. Entire class discussion

The introduction and supporting slides emphasized the importance of understanding the best arguments on all sides (goal interdependence), highlighted the steps in the controversy process, shown below in Figure 1, and reminded the students of the features of skilled disagreement and helpful rules.

Constructive Controversy Procedure

Step	Typical Phrase
Prepare	Our best case Is...
Present	The answer Is...because...
Open Discussion	Your Position is Inadequate because... My position is better because...
Perspective Reversal	Your position Is...because...
Synthesis	Our best reasoned j udgment Is...

Figure 1. Constructive Controversy Procedure

Skilled Disagreement

1. Define "decision" as a mutual problem, not as a win-lose situation.
2. Be critical of ideas, not people (Confirm others' competence while disagreeing with their positions).
3. Separate one's personal worth from others' reactions to one's ideas.
4. Differentiate before trying to integrate.
5. Take others' perspectives before refuting their ideas.
6. Give everyone a fair hearing.
7. Follow the canons of rational argument.

Rules for Constructive Controversy

1. I am critical of ideas, not people. I challenge and refute the ideas of the opposing group, but I do not indicate that I personally reject them.

2. I remember that we are all in this together, sink or swim. I focus on coming to the best decision possible, not on winning.
3. I encourage everyone to participate and to master all the relevant information.
4. I listen to everyone's ideas, even if I don't agree.
5. I restate what someone has said if it is not clear.
6. I first try to bring out all the ideas and facts supporting both sides, and then I try to put them together in a way that makes sense.
7. I try to understand all sides of the issue.
8. I change my mind when the evidence clearly indicates that I should do so.

The remainder of the slides guided students through the controversy process. As noted above, the entire set may be downloaded.

With a program goal of creating the next generation of teachers and a class design philosophy of being transparent in all teaching methods and activities, we gave the students a brief introduction to constructive controversy as a teaching and learning tool. After explaining the mechanics, we put students into pairs and gave them their primary argument roles. Students then watched the video based on their initial argument perspective. Following the video, the students engaged in constructive controversy. The final aspect of the activity was a reflection and discussion with the entire class on the content and process.

Initially the instructors were concerned that students would not find enough controversial material to engage in a meaningful discussion or that students might struggle to accept their assigned roles over their preferred side of the argument. Our fears were immediately dispelled in the few moments after the video as students spontaneously leaped into the point of the activity. One student called out, "How can we have an argument when the answer is so obvious: the video displayed design work!” Then the student explained why she felt this way, giving a clear reason. A second student immediately responded that it was not design and offered a reason. The first student seemed to become aware of the rigidity of her own thinking and the purpose of the entire activity. We all agreed that this learning activity could not have been better!

Feedback during the reflection portion of the activity suggested that students generally enjoyed the constructive controversy as a way to explore a discussion topic and to practice crafting arguments. The students in the engineering education PhD program play dual roles as students and future teachers so their feedback from both perspectives is important. As potential future instructors, the students in our class also saw constructive controversy as an important teaching tool.

Students engaged in the activity with different levels of vigor. Some students, particularly those who seem to enjoy a good argument as a means of discussion, latched right on to their assigned roles and argued passionately for their positions. Other students found accepting a role that might not match their personal position to be slightly more challenging. However, these engagement patterns were similar to those observed in the previously referenced Leadership, Policy and Change course where students had more choices and preparation time in the controversy activity. In the Leadership, Policy and Change graduate level ENE course, constructive controversy was used to explore policy initiatives in STEM education. In this application, students were allowed to select their own topics of argument from a given list and were allowed to select their own side of the argument. In this course, students also did most of their preparation work outside of class and brought the final arguments to class. Both classes incorporated structures that encouraged regular engagement of the students with their peers so the constructive controversy activity was familiar in that regard. In both applications, all class members participated, although varying levels of passion were observed. This suggests that flexibility in structuring the activity is possible without sacrificing participation perhaps with the caveat that students are familiar with peer engagement. Further, although we did not use such an approach, constructive academic controversy could be paired with Quick Thinks (Robinson & Cooper, this volume) either in individual groups or as a whole class to spark deeper thinking and enhanced participation.

Based on our experience in the History and Philosophy of Engineering Education course, we believe that future uses of constructive controversy could be enhanced by adding an opportunity for reflection specifically on the aspect of supporting claims with evidence. Such an opportunity, combined with coaching on meta-reflection, would help students better connect their constructive controversy experience to the importance of supporting claims with reasons and evidence. We agree with Nuhfer and Panitz (this volume) that reflection is a very important part of the cooperative learning process. In addition to contributing to the development of an appreciation for cooperative learning and an awareness of changes in personal learning strategies, we also believe reflection reinforces the content learning itself as well as in connection to the overall course learning objectives.

For this activity and as a whole, students generally responded positively to our transparent approach to teaching, i.e., they appreciated the modeling of tools they could practice and incorporate into their own teaching toolboxes.

Conclusion

The principal question addressed in this chapter is “Can we increase the rate of development of the theory and practice needed to prepare engineering graduates for 21st century opportunities and challenges through the use of cooperative learning strategies such as constructive controversy?" Through application of constructive controversy in the context of a PhD-level Engineering Education course, where students are preparing to become future educators of engineering students, we argue that we can. Our evidence is the response of the students both in seeing the importance of differing perspectives on arguments and in their embracing constructive controversy as a teaching/learning tool.

References

Allen, D. E., Duch, B. E., & Groh, S. E. (1996). The power of problem-based learning in teaching introductory science courses. New Directions for Teaching and Learning. In *Wilkerson, LuAnn & Gijselaers, Wim H. (Eds.) Bringing problem-based learning to higher education: Theory and practice.* San Francisco: Jossey-Bass.

Astin, H. S., & Astin, A. W. (1996). *A social change model of leadership development*. Los Angeles, CA: The Regents of The University of California.

Axelrod, R., & Cohen, M. D. (2001). *Harnessing complexity: Organizational implications of a scientific frontier*: New York: Simon & Schuster.

Beichner, R. J., Saul, J. M., Allain, R. J., Deardorff, D. L., & Abbot, D. S. (2000). *Introduction to SCALE-Up : Student-centered activities for large enrollment university physics.* Paper presented at the Annual Meeting of the American Society for Engineering Education, St. Louis.

Block, P. (2002). *The answer to how is yes*. San Francisco: Berrett-Koehler Publishers.

Booth, W. C., Colomb, G. G., & Williams, J. M. (2008). *The Craft of Research* (3rd ed.): University of Chicago Press.

Dori, Y. J., & Belcher, J. (2005). How does technology-enabled active learning affect undergraduate students' understanding of electromagnetism concepts? *The Journal of the Learning Sciences, 14*(2), 243-279.

Dori, Y. J., Belcher, J., Bessette, M., Danzinger, M., McKinney, A., & Hult, E. (2003). Technology for active learning. *Materials Today, 6*(12), 44-49.

Duch, B. J., Groh, S. E., & Allen, D. E. (2001). *The power of problem-based learning: A practical "how to" for teaching undergraduate courses in Any discipline*. Sterling, VA: Stylus Publishing.

Duderstadt, J. J. (2008). *Engineering for a Changing World*. Ann Arbor: The University of Michigan.

Dweck, C. S., & Leggett, E. L. (1988). A social cognitive approach to motivation and personality. *Psychological Review*, *95*(2), 256-273.

Felder, R. M. (1995). A longitudinal study of engineering student performance and retention. IV. Instructional methods and student responses to them. *Journal of Engineering Education*, *84*(4), 361-367.

Felder, R. M., Sheppard, S. D., & Smith, K. A. (2005). A new journal for a field in transition. *Journal of Engineering Education*, *94*(1), 7-10.

Galloway, P. D. (2007). *The 21st-century engineer: A proposal for engineering education reform.* Reston, VA: American Society for Civil Engineers.

Johnson, D. W., & Johnson, R. T. (1987). *Creative controversy: Intellectual challenge in the classroom*. Edina, MN: Interaction Book Company.

Johnson, D. W., & Johnson, R. T. (2007). *Creative controversy: Intellectual challenge in the classroom* (4th ed.). Edina, MN: Interaction Book Company.

Johnson, D. W., Johnson, R. T, & Smith, K. A. (1991). *Cooperative learning: Increasing College Faculty Instructional Productivity.* ASHE-ERIC Higher Education Report No. 4. Washington, D. C.: The George Washington University School of Education and Human Development.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1997). *Academic controversy: Enriching college instruction with constructive controversy*. Washington, D.C.: The George Washington University.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college: What evidence is there that it works? *Change: The Magazine of Higher Learning 30*(4), 26-35. Retrieved 1 February 2009 from http://www.laspositascollege.edu/facultystaff/documents/CooperativeLearning.pdf

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2000). Constructive controversy: The power of intellectual conflict. *Change: The Magazine of Higher Learning 32*(1), 28-37.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2006). *Active learning: Cooperation in the college classroom* (3rd ed). Edina, MN: Interaction Book Company.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review, 19*(1), 15-29.

Lunsford, A. A., Ruszkiewicz, J. J., & Walters, K. (2004). *Everything's an Argument: With Readings*: Boston: Bedford Books.

Lynn, L., & Salzman, H. (2006). Collaborative advantage: New horizons for a flat world. *Issues in Science and Technology, Winter 22*(2), 74-82.

Lynn, L., & Salzman, H. (2007). The real global technology challenge. *Change: The Magazine of Higher Learning, 39*(4), 8-13.

MacGregor, J., Cooper, J., Smith, K., & Robinson, P. (2000). *Strategies for energizing large classes: From small groups to learning communities*. San Francisco: Jossey-Bass.

Miller, J., & Page, S. E. (2007). *Complex adaptive social systems: The interest in between*

Princeton, NJ: Princeton University Press.

Millis, B. J., & Cottell, P. G. (1997). *Cooperative Learning for Higher Education Faculty*. Phoenix: Oryx Press

NAE. (2004). *The Engineer of 2020: Visions of Engineering in the New Century*

NAE. (2005). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century Committee on the Engineer of 2020*.

Page, S. E. (2007). *The difference: How the power of diversity creates better groups, teams, schools, and societies.* Princeton, NJ: Princeton University Press.

Pink, D. H. (2005). *A whole new mind*. Riverhead, NY: Riverhead Books.

Pink, D. H. (2006). *A whole new mind. Or Why the Right-Brainers will Rule the Future* [DVD].

Pintrich, P. R., & De Groot, E. (1990). Motivational and self-Regulated learning components of classroom academic performance. *Journal of Educational Psychology, 83*, 33-40.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change - The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, July 2004,* 1-10.

Redish, E. F., & Smith, K. A. (2008). Looking beyond content: Skill development for engineers. *Journal of Engineering Education Special Issue, July (In Press)*.

Rowland, G. (2004). Shall we dance? A design epistemology for organizational learning and performance. *Educational Technology Research and Development, 52*(1), 33-48.

Smith, K. A. (1984). Structured Controversy. *Journal of Engineering Education, 74*(5), 306-309.

Smith, K. A. (1995, March). Cooperative learning: Effective teamwork for engineering classrooms. *IEEE Education Society/ASEE Electrical Engineering Division Newsletter,* pp. 1-6.

Smith, K. A. (1996). Cooperative learning: Making "groupwork" work. In C. Bonwell & T. Sutherlund, Eds., *Active Learning: Lessons from Practice and Emerging Issues.* (pp. 67, 71-82). San Francisco: Jossey-Bass.

Smith, K. A. (1998). Grading cooperative projects. In B. Anderson & B.W. Speck, Eds., *Changing the way we grade student performance: Classroom assessment and the new learning paradigm. New Directions for Teaching and Learning* (pp. 78, 59-67). San Francisco: Jossey-Bass.

Smith, K. A., Cox, M., & Douglas, T. C. (2008). Supportive teaching and learning strategies in STEM education. In Baldwin, R. (Ed.), *Creating a culture/climate that supports undergraduate teaching and learning in STEM., New Directions for Teaching and Learning*. San Francisco: Jossey-Bass.

Smith, K. A., Johnson, D. W., & Johnson, R. T. (1981a). Structuring Learning Goals to Meet the Goals of Engineering Education. *Journal of Engineering Education, 72*(3), 221-226.

Smith, K. A., Johnson, D. W., & Johnson, R. T. (1981b). *The Use of Cooperative Learning Groups in Engineering Education.* Paper presented at the Eleventh Annual Frontiers in Education Conference, Rapid City, SD.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education Special Issue on the State of the Art and Practice of Engineering Education Research, 94*(1), 87-102.

Steering Committee. (2006). The Research Agenda for the New Discipline of Engineering Education. *Journal of Engineering Education*, *95*(4), 257-261.

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