



Overview: Cooperative Learning

Cooperative learning has received considerable attention as a strategy for students who are a minority in an educational setting. Always a component of an engineer's education, cooperative work has gained popularity as an alternative to the lecture-based classroom. Results have been positive for both genders in terms of achievement, retention, and attitudes toward learning. Consider the following:

- Studies on students in science, technology, engineering and mathematics (STEM) courses show that various forms of small-group learning are effective in promoting academic achievement, favorable attitudes toward learning, and increased persistence in STEM courses and programs, as well as preparing undergraduate students for the collaborative nature of scientific work. (Springer, Stanne, & Donovan, 1997)
- Even among those who are attracted to engineering's competitive and sometimes solitary style, female students have a greater preference for group learning than their male peers. (Felder, Felder, Mauney, Hamrin, & Dietz, 1995)
- When students adhere to traditional gender roles within groups, group work may perpetuate inequity in a way that causes women to question their sense of competency and belonging in engineering. Instead of transforming the learning environment, collaborative work can reinforce existing patterns. (Mayberry, 1998); (Tonso, 1996a)

Significant caveats are in order. An examination of women's experiences in cooperative learning reveals the complex connections among learning styles, self-perceptions, hands-on experience with laboratory equipment and materials, relationships with peers, and pedagogical approaches in the classroom. Within these interactions exists ample opportunity for either reinforcement or transformation of the status quo. Neither is guaranteed by the simple assignment of "group work." Rather, the instructor is called upon to demonstrate a complex set of sophisticated skills with sensitivity to individual students, group dynamics, and the requirements of the material content of the coursework. *When the practitioner attends carefully to these elements of the cooperative learning environment and follows guidelines that ensure cooperation in group work*, students learn course material better and they also can come to an understanding that they do belong in the engineering classroom.

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Cooperative Learning

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Cooperative Learning: Definitions

Johnson, Johnson and Smith (1991) define cooperative learning as "the instructional use of small groups so that students work together to maximize their own and each other's learning" (p. 12). They also define three broad categories for cooperative learning groups: formal cooperative learning groups used to teach content and problem-solving skills, informal cooperative learning groups that ensure active cognitive processing during a lecture, and cooperative base groups that provide long-term academic support. To be genuinely cooperative, each type of group requires the presence of five basic elements. These are "positive interdependence (a sense of sink or swim together); individual accountability (each team member has to contribute and learn); interpersonal skills (communication, trust, leadership, decision making, and conflict resolution); face-to-face promotive interaction, and processing (team reflection on how well the team is functioning and how to function even better)" (Johnson & Johnson, 2002a).

In their meta-analysis of the effects of small group learning on undergraduates in mathematics, engineering, and technology Springe, Stanne, and Donovan (1997) identify the groups they included as cohort groups, and investigated various types of structured cooperative learning, brief activities for pairs of students during breaks in lectures, and several types of informal collaborative work among students. They found: 1) links and commonalities among the procedures and important differences in underlying assumptions and methods of implementation; 2) substantial differences in how particular practices are implemented; and (3) notable similarities among divergent procedures.

The above definitions provide a starting point for this treatment of cooperative work. The literature regarding research and theory specific to women in engineering is less exact. Often, details that would allow the reader to classify the type of group work or determine the details of an implementation strategy are missing. Further, many authors use the words "collaborative" and "cooperative" interchangeably, where others insist upon a clear distinction. Therefore, specific and unique details about the assumptions, goals, and implementation of a particular group will be provided only when available and appropriate. Even with these omissions of detail and the variations in the groups under discussion, researchers report remarkable similarities in participants' experiences within the groups that are the focus of this paper.



Gender, Cooperative Learning, and Engineering Education

The popularity of teaching and learning in small groups in the engineering classroom has fluctuated over the years, with recent gains. Historically engineering education was oriented toward immediate entry into industry and comprised almost exclusively practical, hands-on courses in which students were actively involved. Likewise, the professor's primary job was to teach and conduct a minimum amount of applied research. This approach began to change when World War II demanded advanced technological innovations and was expedited with the Soviet launching of Sputnik, which ignited America's competitive spirit for space exploration. By the mid 1950s, engineering educators turned their attention to theoretical research and conveyed information to students through lectures with diminished emphasis on hands-on and group work (Wankat, Fleder, Smith, & Oreovicz, 2002).

In recent years, the pendulum has again moved in the direction of cooperative learning in the engineering classroom. The Accreditation Board for Engineering and Technology (ABET), developingt Engineering Criteria 2000, stated that graduates must demonstrate an ability to function on multi-disciplinary teams (Accreditation Board for Engineering and Technology, 1998). This move is due to both the disadvantages of lecture-based pedagogy and to the advantages of cooperative learning. The lecture-based approach is not appropriate for many hands-on engineering outcomes or other outcomes typically accomplished in industry in groups. Nor does it accommodate a diversity of learning styles (see Felder & Silverman, 1988, for further discussion on teaching and learning styles in the engineering classroom). The traditional engineering classroom may even keep away qualified and talented students (Seymour & Hewitt, 1997). Research has shown that female engineering students find traditional classrooms with large lectures alienating, the classroom environment overly competitive and prohibitive of inquiry, and the professors inaccessible (Seymour & Hewitt, 1997); (Bergvall et al., 1994); (Metz, Brainard, & Gillmore, 2001).

Cooperative learning has often been proposed as a solution to the adverse effects of the lecture-based learning environment upon women. The work of Carol Gilligan, along with the book *Women's Way's of Knowing* (Belenky, Clinchy, Goldberger, & Tarule, 1996), usually provides the research basis for this assertion. In *The Chilly Classroom Climate: A Guide to Improve the Education of Women* (1996), Sandler, Silverberg and Hall map out a commonly accepted line of reasoning that supports cooperative learning as antidote to lecture-based learning Carol Gilligan suggests that "many more women than men define themselves in terms of their connection to others," based on her work regarding the moral reasoning of women and girls (cited in Sandler, Silverberg, & Hall, 1996, p. 42). Building on Gilligan's work, Belenky et al. identify alternative frameworks to describe women's perspectives in educational settings. Included in "women's ways of knowing" is the acceptance of subjective knowledge and the view that all knowledge is contextual. Belenky et al do not posit a biological basis for learning differences; they claim, rather, that the cause is gender socialization. Women's socialization teaches them to value and perfect their interpersonal skills (Valian, 1998). Indeed, women engineering students rate among their top abilities cooperation and the ability to understand others (O'Hare, 1995). Some studies have shown that female students have a greater preference for group learning than their male peers (Felder et al., 1995) even among those who are attracted to engineering's competitive and solitary style (Bergvall et al., 1994).

It must be noted that the assertion that women have different learning styles from men is controversial and the idea that women have a greater preference for cooperative learning than men *is not strongly substantiated in the research literature*. Sandler concedes, "While the



vast majority of traditional research on collaborative learning is neither gender specific nor race specific, research in women's studies and feminist pedagogy strongly suggests that many women are particularly well served in less competitive, more collaborative educational settings" (p. 44). Moreover, cooperative learning has proven effective for both genders, if not always in greater proportion for girls and women.

Positive Impacts of Cooperative Learning

Although women's preferences for cooperative learning as compared with men's may not have received much research attention, the effect of cooperative learning for all students has, and the results are positive for both genders. The results of the meta-analysis conducted by Springer, et. al. (1997) on students in science, technology, engineering and mathematics (STEM) courses show that various forms of small-group learning are effective in promoting academic achievement, favorable attitudes toward learning, increased persistence in STEM courses and programs, and preparing undergraduate students for the collaborative nature of scientific work. In small groups, students teach and learn from each other (Haller, Gallagher, Weldon, & Felder, 2000), develop more sophisticated forms of communicating technical information (Tonso, 1996b) and, through cooperative interactions, learn to behave as a team of engineers (Mayberry, 1998).

Potential Problems in Cooperative Learning

Having determined that cooperative learning is advantageous for both genders, and perhaps more so for women, it is important to turn attention to some potential problems. However promising group work may seem to be for women's learning, certain behaviors and scenarios can have the often unintended result of negating the beneficial effects of a cooperative environment (Tonso, 1996a; Rossner, 1998). In particular, students' adherence to traditional gender roles within groups and/or group work may perpetuate inequity in a way that causes women to question their sense of competency and belonging in engineering. Instead of transforming the learning environment, collaborative work can reinforce existing patterns (Mayberry, 1998; Tonso, 1996a).

Research by Felder et. al, for example, found through self-report and observation of videotapes that women played less active roles in groups than did men. Men believed the greatest benefit of group work was the opportunity to explain material to others, but this activity also caused them to believe that they were doing more than their fair share of work. Conversely, women felt that having material explained to them was the greatest benefit of group work. This reflected their belief that they needed external help and personal interaction to succeed. Women also felt that their contributions in the group were devalued and discounted by male classmates. Subsequently, their confidence levels decreased as time went by (Felder et al., 1995). Similarly, Mouring (1998) concluded from student focus groups that female students report difficulty in achieving equal standing with men on a team. Women reported that they were given organizational and supporting roles rather than technical and leadership roles. Their ideas and suggestions were discounted and feelings of isolation were the result. The men in these teams found the women too emotional, thought the women played politics, and that they did not have to perform certain tasks.

These types of behaviors are also present in hands-on and laboratory sessions. Instead of gaining confidence and expertise in the practice of engineering, Seymour & Hewitt (1997) found that in undergraduate lab classes, males took charge, ordered women, gave help women



did not ask for, and took credit for work they had not done. Women and men both had difficulty in relinquishing traditional roles, frustrating the few women who had. This experience is echoed by academic women scientists who were asked, “How does the laboratory climate (or its equivalent in your sub-discipline) impact upon the careers of women scientists?” (Rosser, 2000). Although this question was asked of highly successful women, their answers indicate the degree of difficulty for women in earlier stages of their scientific careers as well as the dual nature of the lab experience for women. The largest number of respondents suggested that their gender led to their being perceived as a problem, anomaly, or deviant in their laboratory/work environment. Others had very positive or mixed experiences. The following participant’s comment illustrates this point:

“...I have observed women to be overall more outgoing and willing to be team players, making them excellent contributors to research performed by a group of people. The women are the ones who organize the others. This is a double-edged sword, because we end up ‘serving’ others who are not so community minded, but in that this behavior is for the greater good, it also serves the woman. Women are included in the intellectual environment of the lab and promote its openness. Given these positive roles for women in the lab, I do not see environment as a component of the proportionate loss of women in the higher ranks of academia. It is likely that precisely because they are such good team players, women are less good at ‘blowing their horn’ in job application/interview situations, and this hurts them for sure.”

This research demonstrates the power of peer interactions during group work in classroom and laboratory settings. Clearly, the many benefits of cooperative small group work are available only with careful overall pedagogical planning and implementation that explicitly addresses gender-based inequities as well as how to work effectively in a team (see strategies below).

The fact that problems can occur in cooperative work environments is articulated and disseminated to faculty to emphasize the real need for faculty intervention and innovative, well-designed pedagogy rather than simply to deter them from these strategies.

Successful Strategies for Cooperative Learning

Group work experiences that yield maximum benefits for all participants require careful planning and attention to details. The challenge to educators is to ensure that assigned group work enhances learning, increases feelings of self-efficacy, enhances individual participant’s sense of belonging in the engineering classroom through sincere team efforts, and passes on the positive aspects of the culture of engineering so that students become professionals without also perpetuating another generation of marginalizing behavior. Ensuring that group work is conducted in a truly cooperative manner creates an atmosphere in which these outcomes can happen. Encapsulating these ideas, Johnson and Johnson (1998) provide the following advice on how to fulfill the five requirements of cooperative group work requirements:

- **Positive Interdependence.** Each student must perceive that she or he cannot succeed unless all others in the group succeed as well. Tactics include adding joint rewards, dividing resources, and requiring complimentary roles.



- **Individual Accountability.** Individuals perform better as a result of cooperative learning. Giving individual tests, having students explain what they have learned to a classmate, or observing each group and documenting individual contributions can encourage accountability.
- **Face-to-Face Promotive Interaction.** Keep the size of the group small so that students may help, support, encourage and praise one another's efforts. Students should verbally explain how to solve problems, teach each other, and connect past and present learning, as well as challenge one another's reasoning and conclusions, facilitate learning efforts and provide modeling. In this way, students receive and provide verbal and nonverbal feedback.
- **Social Skills.** Leadership, decision-making, trust-building, communication, and conflict management skills must be taught, just as academic skills are taught.
- **Group Processing.** Students should identify what member actions were helpful in ensuring effective working relationships and that all group members achieved learning goals. They also decide which behaviors to keep and which to change. Successes should be celebrated.

These criteria for effective teamwork underscore the need for the intensive involvement of the instructor, well beyond choosing a task that is appropriate for group work. To ensure that team behaviors produce the results conducive to equitable learning environments, team *processes* must be made an explicit part of the task. These requirements must be addressed directly, before, during, and after the assignment, with corrections made mid-course if necessary. Feedback mechanisms and peer team evaluations should also be part of student assessment. Implementing these basic strategies should help cooperative group work fulfill its promise to female students.

Rosser (1998) makes suggestions that specifically address some of the gender issues in implementing group work.:

- **Group Composition.** Including more than one person of a minority race or gender in each group may lead to less isolation.
- **Role Rotation.** Initially, group members may be allowed to choose their own roles so that they can develop security within the group. These roles must be rotated, however, so that each individual can gain experience and skills.
- **Project Choice.** Projects and problems should draw upon the experiences and issues significant to the genders of participants.
- **Grading.** Grades should be assigned to reflect the importance of group work to the goals of the course. Instructors must maintain an awareness of the ways that race and gender can interact with group dynamics to influence student peer assessments. Although the goal of equity oriented group work is to eliminate bias, it is still possible that the communication styles, personality traits, and the culture of the engineering classroom can work against student perceptions of the quality of women's contributions in small groups.

Read the work of Rosser and Johnson and Johnson for more prescriptive instructions for conducting quality group work. The web page of The Cooperative Learning Center at the University of Minnesota, co-directed by Johnson and Johnson (2002a) at: <http://www.clcrc.com/>



provides extensive information on the subject and also makes available a question and answer forum where educators can address practical matters.

Assessment of Cooperative Learning

The discussion on gender and cooperative group work emphasizes the ways that multiple interdependent factors interact to create students group learning experience. Learning styles, pedagogical decisions and peer interactions within small groups contribute to the classroom climate in which female students develop their sense of belonging and self-efficacy as engineers. In turn, these factors may affect and be affected by the students' quality of learning and retention rates. Improvement in one area may indirectly spur improvement in another. Therefore, to measure the success of cooperative group learning, any one or a combination of factors may be assessed using one or more instruments and methodologies.

The instruments and methodologies chosen for assessment must be clearly connected with the goals of the intervention and be designed to measure the constructs meant for improvement. For example, if group work is initiated to convey a sense of social belonging in the engineering program, a scale measuring a sense of social belonging is a more precise instrument than grade point average. In some Women in Engineering (WIE) programming, the construct measured is very closely related to the measurement instrument, as is the case with visual spatial skills. The goal of improving visual spatial skills is simply measured by a specified visual spatial skills test. In contrast, a cooperative learning intervention may have any number of outcomes as its goal. Because of this, a great number of measurement instruments and assessment methodologies are available for assessing any single cooperative learning outcome. The converse is also true: one type of methodology can be applied to a multitude of outcomes.



A review of the cooperative learning assessment methods used in studies reported in the *Journal of Engineering Education* reveals that assessments tend to be based on surveys and end of semester student ratings geared towards satisfying funding reviewers. Comparisons of experimental and control group tests and retention rates are used only occasionally (Wankat, 1999; Wankat et al., 2002, p. 7). Springer et al's meta-analysis (1997) found that most common measurements in field research were grades (based on non-standardized tests) and standardized tests, with the former yielding more positive results. In addition to these techniques, a number of less commonly used qualitative assessment methods have been used for group learning. These may include, but are not limited to:

- Attitudinal questionnaires (Rosser & Kelly, 1994)
- Focus groups (Mead et al., 1999)
- Interviews (Booth, 2001)
- Conversation analysis (Haller et al., 2000)
- Direct observation (Jovanovic & King, 1998)
- Case study (Trytten, 2001); (Tonso, 1996b)
- Video recordings (Golbeck & Sinagra, 2000).

While yielding rich results, these methods are expensive and time-consuming. Results are difficult to interpret and there are few examples to replicate. Further, the education and training of engineering faculty makes them more comfortable with quantitative data (Wankat et al., 2002).

The assessment methodologies discussed above can be applied to any number of constructs (as defined by the goals of the program) or outcomes. Johnson & Johnson's *Meaningful Assessment: A Manageable and Cooperative Process* (2002b) gives detailed information to practitioners on using goal-setting, standardized and teacher-made tests, compositions and presentations, projects, student portfolios, observation of students, assessment of social skills and student attitudes, interviews, learning logs, and journals to assess student achievement.

Examples of Cooperative Learning Interventions

Opportunities for using group work as a catalyst for gender equity range from isolated but targeted activities to more far reaching efforts to integrate gender-aware teaching throughout girls' and women's educational experiences. An excellent resource for locating examples of group work with engineering students is the WEPAN conference proceedings. Another resource is the *New Formulas for America's Workforce: Girls in Science and Engineering*, published in 2003 by the National Science Foundation.



Works Cited

- Accreditation Board for Engineering and Technology, I. (1998). *Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States* (2nd ed.). Baltimore: Engineering Accreditation Commission.
- Belenky, M. F., Clinchy, B., Goldberger, N., & Tarule, J. (1996). *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. New York: Basic Books.
- Bergvall, V. L., Sorby, S. A., & Worthen, J. B. (1994). Thawing the freezing climate for women in engineering education: Views from both sides of the desk. *Journal of Women and Minorities in Science and Engineering*, 1, 323-346.
- Booth, S. (2001). Learning computer science and engineering in context. *Computer Science Education*, 11(3), 169-188.
- Felder, G., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education*, 78(7), 674-681.
- Felder, R., Felder, G., Mauney, M., Hamrin, C., & Dietz, J. (1995). A longitudinal study of engineering student performance and retention. III. Gender differences in student performance and attitudes. *Journal of Engineering Education*, 84(2), 151-163.
- Golbeck, S. L., & Sinagra, K. (2000). Effects of gender and collaboration on college students' performance on a Piagetian spatial task. *The Journal of Experimental Education*, 69(1), 22-35.
- Haller, C. R., Gallagher, V., Weldon, T. R., & Felder, R. M. (2000). Dynamics of peer education in cooperative learning workshops. *Journal of Engineering Education*, 89(3), 285-293.
- Johnson, D. W., & Johnson, R. T. (1998). Cooperative learning returns to college: What evidence is there that it works? *Change*, 30(4), 26-36.
- Johnson, D. W., & Johnson, R. T. (2002a). *The Cooperative Learning Center at University of Minnesota*. Available: <http://www.clcrc.com> [2002, October 2, 2002].
- Johnson, D. W., & Johnson, R. T. (2002b). *Meaningful Assessment*. Boston: Allyn and Bacon.
- Johnson, D. W., Johnson, R. T., & Smith, K. A. (1991). *Cooperative Learning: Increasing College Faculty Instructional Productivity*. Washington, D.C.: The George Washington University, School of Education and Human Development.
- Jovanovic, J., & King, S. S. (1998). Boys and girls in the performance-based science classroom: who's doing the performing. *American Educational Research Journal*, 35(3), 477-496.
- Mayberry, M. (1998). Reproductive and resistant pedagogies: The comparative roles of collaborative learning and feminist pedagogy in science education. *Journal of Research in Science Teaching*, 35(4), 43-459.
- Mead, P., Moore, D., Natishan, M., Schmidt, L., Brown, S., Lahtan, C., Goswami, I., & Mouring, S. (1999). Faculty and student views on engineering student team effectiveness. *Journal of Women and Minorities in Science and Engineering*, 5, 351-363.
- Metz, S., Brainard, S., & Gillmore, G. (2001). *WEPAN Pilot Climate Survey*, [Internet]. WEPAN [2002, March 21, 2002].
- Mouring, S., Schmidt, L., Mead, P., Natishan, M., Moore, D., & Lahtan, C. (1998). The Esteam program: Changing the paradigm on engineering students teams from diversity to training for diversity. In B. Bogue & P. Guthrie & B. Lazarus & S. Hadden (Eds.), *Tackling the Engineering Resources Shortage: Creating New Paradigms for Developing and Retaining Women Engineers* (pp. 119-125). Montreal: The International Society for Optical Engineering.



- O'Hare, S. (1995). Freshmen women in engineering: Comparison of their backgrounds, abilities, values, and goals with science and humanities majors. *Journal of Women and Minorities in Science and Engineering*, 2, 33-47.
- Rosser, S. (1998). Group work in science, engineering and mathematics: Consequences of ignoring gender and race. *College Teaching*, 46(3), 82-89.
- Rosser, S. (2000). Gender equity issues in science careers. *WEEA Digest*, 3+.
- Rosser, S., & Kelly, B. (1994). Who is helped by friendly inclusion? A Transformation teaching model. *Journal of Women and Minorities in Science and Engineering*, 1, 175-192.
- Sandler, B., Silverberg, L., & Hall, R. (1996). *The chilly classroom climate: A guide to improve the education of women*. Washington, D.C.: The National Association for Women in Education.
- Seymour, E., & Hewitt, N. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder: Westview Press.
- Springer, L., Stanne, M., & Donovan, S. (1997). *Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis*. Madison: National Institute for Science Education.
- Tonso, K. (1996a). The impact of cultural norms on women. *Journal of Engineering Education*, 85(3), 217-225.
- Tonso, K. (1996b). Student learning and gender. *Journal of Engineering Education*, 85(2), 143-156.
- Trytten, D. A. (2001). Progressing from small group work to cooperative learning: A Case study from computer science. *Journal of Engineering Education*, 85-91.
- Valian, V. (1998). *Why so slow? The advancement of women*. Cambridge: The MIT Press.
- Wankat, P. C. (1999). An analysis of the articles in the Journal of Engineering Education. *Journal of Engineering Education*, 88(1), 37-42.
- Wankat, P. C., Fleder, R. M., Smith, K. A., & Oreovicz, F. S. (2002). The scholarship of teaching and learning in engineering. In M. T. Huber & S. Morreale (Eds.), *Disciplinary Styles in the Scholarship of Teaching and Learning: Exploring Common Ground*. Washington: AAHE/Carnegie Foundation for the Advancement of Teaching.