Journal of Engineering Education
July 2011, Vol. 100, No. 3, pp. 475–497

Collaborative Learning in Engineering Students: Gender and Achievement

GLENDA S. STUMP, JONATHAN C. HILPERT[a], JENEFER HUSMAN, WEN-TING CHUNG, WONSIK KIM
Arizona State University, Indiana University-Purdue University Fort Wayne[a]

BACKGROUND
Collaboration is an ABET accreditation required component of the engineering curriculum. Research has shown that collaborative learning positively influences student achievement. The relationship between motivation, collaborative learning strategies, and achievement is not well studied in an engineering education context.

PURPOSE (HYPOTHESES)
A set of hypotheses were tested that predicted positive relationships between students' self-reported informal collaboration, self-efficacy for learning course material, knowledge building behaviors, and course grade. A second set of hypotheses were tested that predicted gender similarities in reported self-efficacy, and gender differences in reported collaborative learning activities.

DESIGN/METHOD
One hundred fifty engineering students were surveyed for study 1 and 513 students were surveyed for study 2. Bivariate correlations were completed to examine relationship between study variables; multiple regression analysis was completed to examine predictive ability of variables on course grade; MANOVA was completed to examine multivariate relationship between variables.

RESULTS
In study 1, students' reported use of collaborative learning strategies and reported self-efficacy for learning course material were significantly predictive of their course grade. In study 2, female students reported greater use of collaboration as a learning strategy than their male classmates; among male and female students combined, those who received "B's" in their engineering course reported more collaboration than their peers who received "A's" or "C's" and lower.

CONCLUSIONS
Overall, students' self reported collaborative learning strategies were associated with increased self-efficacy for learning course material and course grade, particularly for students who received "B's" in the course. Female students reported greater use of collaborative learning strategies than their male peers.

KEYWORDS
achievement, collaborative learning, gender

INTRODUCTION

Traditional engineering educational strategies such as lecture, lab experiences, and homework have been criticized because they inadequately prepare engineering students to engage in the collaborative partnerships that are essential for the practicing engineer (Kalonji, 2005). These methods have also been criticized because they promote passive learning and a compartmentalized curriculum that may not prepare students for the innovative and flexible role of engineers in today's society (Duderstadt, 2008; Guzdial et al., 2001; Heywood, 2008; Prince, 2004). Suggested reforms to engineering education have included incorporation of collaborative learning in the curriculum as a means of preparation for future practice. Research has shown a more immediate benefit of collaboration, in that this more active form of learning can also positively influence students' achievement, persistence, and attitudes about learning (Bowen, 2000; Prince, 2004; Springer, Stann, & Donovan, 1999).

In an educational context, collaboration is generally described as an approach involving joint intellectual efforts between students, or between students and the instructor (e.g., Smith & MacGregor, 1992). Despite recognition by the private sector that collaboration is a vital skill for the practicing engineer, and acknowledgment by researchers that collaborative learning contributes to academic achievement, much of the engineering education literature describes engineering curriculum as oriented toward student retention of facts and analytical skills (Felder & Brent, 2005; French, Immekus, & Oakes, 2005; Guzdial et al., 2001; Zhang, Anderson, Ohland, & Thorndyke , 2004). Research has suggested that collaborative learning activities are viewed by some educators as impractical in the classroom or as an ABET accreditation requirement that must be superficially met (Guzdial et al., 2001). Given this consideration, *informal* collaboration may be an important means to achieve the benefits of collaborative activities in classrooms where the practice is not routinely used. In their work, Summers, Bergin, and Cole (2009) operationalized informal collaboration as occurring in class, two to five times per semester, and / or related to short-term assignments. In the current studies, we broadened the definition of this term to include ways in which students reportedly engaged in either voluntary or teacher-recommended collaboration both inside and outside of the classroom. Our collaboration survey items evaluated students' perceptions of actively sharing ideas with peers, of obtaining helpful feedback from other students, and of working together to help each other understand the material, learn new things, and complete assignments.

The aforementioned lack of support for collaboration in the engineering classroom may also be a contributing factor to an educational system that has traditionally not recruited or retained women (Vogt, Hocevar, & Hagedorn, 2007). In 2007, women received only 9% of the bachelor's degrees awarded in engineering, although they received half or more of the bachelor's degrees awarded in the biological sciences, psychology, social sciences, agricultural sciences, and chemistry (National Science Foundation [NSF], 2010). In a classic study, Seymour and Hewitt (1997) documented the competitive structure of engineering education; others have described engineering education courses as weed-out systems with impersonal overtones (Sadker & Sadker, 1994). These characteristics are potentially detrimental to female students, who may prefer a more supportive educational environment that includes collaborative learning (Seymour & Hewitt, 1997).

In order to construct a comprehensive picture of the advantages of collaboration in an engineering classroom context and students who benefit from its use, we examined collaboration in two studies: Our first study examined the relationship between self-reported informal student collaboration, self-efficacy, a motivational variable, and students' achievement. We also examined collaboration in relation to other important strategic learning variables (Weinstein, Husman, & Dierking, 2000). We examined students' reported use of knowledge building strategies and perceived teacher directedness in relation to their reported use of collaborative learning strategies and course achievement. Our second study looked more closely at gender differences within engineering programs. This study explored the relationship between student achievement, perceived self-efficacy, and reported use of collaborative learning strategies in relation to students' gender.

THEORETICAL FRAMEWORK

Collaboration as a Constructivist Learning Strategy

As a constructivist strategy, collaboration has roots in both Piagetian and Vygotskian views of learning. Piaget believed that children construct knowledge as they develop and repeatedly interact with their surrounding world (Piaget, 1926). The Piagetian view poses that cognitive conflict encountered by learners while interacting with others kindles their search for and assimilation of new information. Alternatively, the Vygotskian view poses that learners co-construct knowledge by sharing meaning of information in a social context (Vygotsky, 1978). Learners subsequently internalize and use the new meanings that were constructed with others, thus transforming the interpersonal activity into an intrapersonal one. Although Vygotsky often spoke of collaboration as a teaching-learning phenomenon, it has been further researched as a learner-to-learner activity (Mercer, 1996), where a more competent peer might scaffold the learning of a classmate (Webb, 1989; Webb & Mastergeorge, 2003) or peers at similar levels of knowledge might interact (Jeong & Chi, 2007; Smith et al., 2009).

In situations where asymmetry of knowledge between students may exist, collaborative efforts have been shown to benefit the more competent peer, or help-giver, as well as the less-able peer, or help-seeker. When explaining concepts to a peer, the help-giver gains the ability to offer a clear, organized, distanced type of understanding (Fletcher, 1985; Webb, 1989), thus supporting the old adage that the best way to learn something is to teach it to others. In this same situation, the help-seeker has potential to benefit (Webb, Troper, & Fall, 1995), gaining opportunity to assimilate new information into his or her knowledge structures.

Similarly, there is a benefit from collaboration when students at the same level of knowledge interact (Barbieri & Light, 1992; Mason, 1998; Webb, 1989). In these situations, students actively build on statements from each other, and co-construct a new understanding of the material that was unknown to both prior to the interaction. Smith and colleagues (2009) found that students increased their understanding of difficult genetics concepts from in-class discussions, even when there was no 'expert' student in their three-person group. Students in this study articulated that the discussion was more productive and that they retained the information longer because they discussed it at length, examined all possible explanations, and arrived at an understanding collectively. Jeong and Chi (2007) examined knowledge convergence, or increase in common knowledge, between pairs of post-secondary students when learning information from written text. Their work showed that collaborative strategies increased common knowledge for concepts that were explicitly stated in the text, as well as for those that were inferred from text. The amount of collaborative interaction had a greater effect on construction of elaborate inferred knowledge than on simple factual knowledge.

The benefit of collaborative exchanges has been explained by the idea that peer interactions identify gaps in knowledge, stimulate elaboration of knowledge, and thus contribute to individual cognitive gains (Van Boxtel, Van der Linden, & Kanselaar, 2000). This process has potential to play a central role in meaningful knowledge building activities (Oshima, Scardamalia, & Bereiter, 1996; Scardamalia & Bereiter, 1994). Within a constructivist philosophy, knowledge is produced by the learner rather than reproduced; the learner must actively investigate meaning of information, connect it to prior knowledge, construct new meaning, and apply it across contexts (Scardamalia & Bereiter, 1991). Mason (1998) found that when learners collaborate—explain, discuss, and sometimes justify their opinions about concepts to each other—they develop a more generalized and principled understanding of the concepts under discussion, thus facilitating their own construction of meaning. Because of the role collaboration may play in student knowledge construction, it has been found to be significantly correlated with knowledge building behaviors (Husman, Lynch, Hilpert, & Duggan, 2007).

Effective Collaboration

Cohen (1994) suggests that effective or successful collaboration can be operationalized in multiple ways, dependent upon the focus of the observer. For those interested in the social aspects of learning, such as equity of student status within the classroom or positive intergroup relations, effective collaboration may mean equal participation by all members of the group or being cooperative and friendly while working with others. For those interested in cognitive aspects of learning, effective collaboration may mean increased conceptual learning or increased engagement in intellectual discussions to attain higher order thinking. For educators, the more easily measured and hence more common way to operationalize effective collaboration is via student achievement, which is usually measured by exams or standardized testing.

The literature includes numerous studies that attest to the benefit of collaborative learning. Prince's (2004) review of three meta-analyses (Johnson, Johnson, & Smith, 1998a, 1998b; Springer et al., 1999) suggests that collaboration among post-secondary students increases academic achievement on traditional measures and also improves student retention. Hake (1998) reported that within secondary and post-secondary introductory physics classes, interactive learning that included collaboration between peers or between students and the instructor contributed to a significant gain in conceptual understanding of physics principles as evidenced by differences between pre- and post- test scores. The meta-analysis done by Springer and colleagues showed that within science, technology, engineering, and math (STEM) courses, various forms of small group learning effectively increased not only student achievement, but also their persistence and attitudes toward learning. Bowen (2000) found similar results in a meta-analysis of studies completed with secondary and post-secondary science students. Smith et al. (2009) found that in-class peer discussion significantly improved students' understanding of conceptual questions as recorded by using personal response systems ('clickers') in a post-secondary genetics class.

It is important to note however, that not all collaborative activities are successful. Simply putting students together does not guarantee knowledge construction or increased academic achievement (Barron, 2003; Salomon & Globerson, 1989), and researchers have devoted considerable effort to discover the conditions that promote effective and non-effective collaboration. Earlier research examined influences such as ability level (Webb, Nemer, Chizhik, & Sugrue, 1998; Webb & Palinscar, 1996), gender (Gillies & Ashman, 1995; Savicki, Kelley, & Lingenfelter, 1996; Webb, 1989; Wood, 1987), and number of collaborators (Fuchs et al., 2000; O'Donnell & O'Kelly, 1994). These studies produced mixed results, leaving researchers without an irrefutable list of factors that contributed to effective collaboration. Other studies viewing collaboration from a social psychology perspective (e.g., Salomon & Globerson, 1989) attributed non-effective collaboration to roles, such as the 'free rider,' that collaborators assume during the interaction. Slavin (1996) maintained that a common group goal is necessary for collaboration to be effective, and that achievement of the group goal should be evaluated via individual performance of each group member, e.g., a final math unit grade for each group member should be derived from the average of all group members' quiz grades. More recent studies however, have focused on characteristics of the collaborative exchange itself as the unit of analysis.

Qualities of collaboration in equal ability groups. Volet, Summers, and Thurman's (2009) research provides evidence that the quality of interaction facilitates or impedes learning. Their qualitative analysis of post-secondary veterinary science students showed that factors such as asking questions, requesting explanations, giving tentative responses that invited peer commentary, having prerequisite knowledge of the subject matter, and experiencing positive emotions during collaboration all contributed to high level, or in-depth learning and high interaction between group members. Wiley and Bailey (2006) found that post-secondary students who worked collaboratively on an argumentation task in an online environment demonstrated more interaction and co-construction of understanding than students who worked together on a summarization task.

Research completed with younger students has produced similar findings. Barron's (2003) work with sixth-grade students showed that more successful student groups responded to peers' correct problem proposals by accepting or discussing them, whereas less successful groups responded to peers' correct proposals by rejecting or ignoring them. More successful groups also generated proposed solutions that were related to previous discussion, whereas less successful groups often generated unrelated proposals, indicating that students were not attending to the discussion at hand. Howe's (2009) preliminary work with older elementary students showed that unresolved contradictions from collaborative exchanges may be the incentive for students to independently pursue new information that leads to increased learning. Repetition of these studies in samples of post-secondary students is needed before findings should be generalized to engineering students.

Qualities of collaboration in unequal ability groups. When considering peers of unequal ability, studies of learning from human tutoring have provided additional insight into qualities of effective collaboration. In a study with post-secondary students as naturalistic (untrained) tutors and junior high students as tutees, the tutees learned more when they had interactive exchanges with their tutors rather than simply being lectured by them. The interactive exchanges were ones where the tutors used questioning and guided prompting to help the tutees construct and reflect on their responses (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001). Despite a potential imbalance of authority in a tutor-tutee situation, the presence of an interactive exchange was key to the tutee's learning. In work related to effective help-seeking behaviors, Webb and Mastergeorge (2003) stated that help seekers' success seems to be dependent on their ability to ask specific questions related to their area of confusion, demonstrate persistence in help seeking, and apply the information they receive. Webb (1989) also maintained that collaboration is only effective for the help-seeker if explanations are timely, specific to the help-seeker's misconception or lack of understanding, and given at a level of elaboration that the help-seeker needs and comprehends.

These more qualitative lines of research may provide helpful insight into factors that promote effective collaboration under variable conditions. In these studies, the most consistently identified elements of effective collaboration have not been related to quantifiable factors such as ability, gender, or participant number. What seems to matter is that students are engaged in cognitive processes such as identifying gaps in their knowledge, questioning or elaborating on each other's ideas, and coming up with related explanations or solutions. More research is needed to examine the relationship between students' reported engagement in these types of behaviors and their academic achievement.

Barriers to Collaborative Learning in Engineering

Within engineering coursework, competition among students induced by the practice of curve-grading assignments reduces students' willingness to cooperate with their peers (Guzdial et al., 2001; Seymour & Hewitt, 1997). Instructional practices that promote high stakes competition focus students' goals on course grades instead of learning course material; students feel pressured to outperform others or at least show that they can perform as well as other students (Turner et al., 2002). In this environment, high ability students, or those who can readily solve homework problems, may become possessive of their course knowledge and skills; their reluctance to engage in help-giving or sharing information with their peers stems from fear that their helpfulness might improve their peers' grades and possibly reduce their own chances of being at the top of the class (Guzdial et al., 2001; Seymour & Hewitt, 1997). If students believe that their primary goal is to compete for class position, subsequent reluctance to collaborate with peers may further reduce their practice of this critical skill.

A competitive class environment may also influence students' help-seeking behavior as well as their help-giving behavior. Students who are focused on their own achievement may avoid actions that reveal their lack of ability, such as admitting confusion or asking for help (Karabenick, 2004; Ryan, Patrick, & Shim, 2005). Their reluctance to seek help may be driven by a need to preserve their self-worth. Seymour and Hewitt (1997) found a general reluctance of male engineering students to ask questions in class. Educational researchers have consistently found that for many high performing undergraduate students, a belief that understanding course material without expending effort is equated with intelligence or a perceived natural ability (Covington, 2000). Within the engineering classroom, these students may actively choose to perform in isolation in order to 'look smart' and gain respect from their peers.

In addition to concerns about classmates' perceptions of their abilities, some students have also disclosed fear of repercussion from their faculty when asking questions in a competitive class atmosphere (Guzdial et al., 2001). In Seymour and Hewitt's study (1997), male students reported that they avoided asking questions of their faculty, fearing that their questions would not be deemed appropriate use of faculty time. They stated that the faculty might develop a i.e., "bad impression" of them, which could then be reflected in their grade. Female engineering students in the same study reported differing consequences of asking questions. When they risked asking their faculty questions for clarification, female students reported feeling stupid and incompetent.

Lastly, the use of assignments that are perceived to have one right answer serves as a barrier to peer learning approaches by students. Cohen (1994) explained that effective collaboration varies both in amount and character, dependent upon the type of question being asked and the type of learning required. For routine learning where a clear procedure is needed to arrive at a correct answer, effective collaboration may be relatively brief and consist of simply helping one another to grasp what the instructor or textbook is saying. However, this behavior may not be employed in a competitive engineering classroom environment due to reluctance to reveal a lack of knowledge or fear of harming class standing as previously described. Conversely, for conceptual learning needed to answer ill-structured problems with multiple approaches or solutions, collaboration becomes a longer and more necessary endeavor. In this situation, effective interaction becomes a mutual process that includes exchange of ideas and sharing strategies for solving the problem (Cohen, 1994). Even though faculty claim that one-answer problems are not the norm in engineering education, student perceptions have been found to differ (Guzdial et al., 2001). Regardless of faculty intent, if students believe that engineering problems have one correct answer and are solved via established procedures, their perceived need for collaborative input may be significantly reduced.

Additional Variables Influencing Peer Collaboration

Teacher directedness. Students' approaches to learning through activities such as peer collaboration and knowledge building may be influenced by perceptions of additional variables in the classroom environment, such as their teachers' instructional style. Preliminary research suggests that teachers who provide clear direction and feedback to their students may support students' active engagement in the learning environment, especially in the early post-secondary years (Stump, Hilpert, & Husman, 2008). Although teacher directedness can be thought of as controlling behavior, which has been associated with lack of student self-regulation (Shell et al., 2005), classroom conflict, and tension (McCaslin & Good, 1992), we argue that as students transition from directive and supportive secondary education to potentially less directive and less supportive post-secondary educational environments, directive teachers may actually scaffold students' self-regulation behaviors and learning strategies. Directive instructors may help students understand the value of their course materials and guide their use of learning strategies appropriate for these new environments.

Self-efficacy. Another factor related to collaborative learning strategies (Moriarty, Douglas, Punch, & Hattie, 1995) and student achievement (e.g., Bandura & Locke, 2003; Britner & Pajares, 2006) is self-efficacy, or the belief that one can successfully perform the task at hand (Bandura, 1997). Following a review of existing research, Linnenbrink and Pintrich (2003) generalized that self-efficacy strongly influences students' behavioral engagement in learning; those who feel efficacious about their ability to learn material are more likely to exert effort, persist, and adaptively seek help when necessary. Taken together, the research results may also indicate that students who feel efficacious about their ability to master course material are more willing to discuss or share their new knowledge with others.

Gender and Engineering

Although previous studies have reported that female students in engineering programs had higher attrition rates and lower GPAs than males, contemporary research suggests that female students in Science and Engineering (S&E) programs have ceased falling behind in the pipeline (Vogt et al., 2007); they are more likely than male students to complete an S&E degree and less likely to switch to a non-S&E program (Huang, Taddese, Walter, & Peng, 2000). Although still underrepresented by sheer numbers in engineering degree programs, women in the twenty-first century who do enroll in these programs seem likely to do well as evidenced by these statistics. However, their persistence in engineering programs does not mean that they feel welcomed or accepted there. Vogt and colleagues (2007) found that female students in engineering programs were more likely to report faculty bias and discrimination as well as the persistent belief that their male counterparts did not respect them as equals. Despite these findings, the same authors found that females' self-efficacy for engineering remained resilient. Another study found that females were more likely than males to collaborate or seek help from peers during group work even when they perceived themselves to be a low status member of the group (Seymour & Hewitt, 1997). Researchers have emphasized the importance of creating positive collaborative experiences for female engineering students where they are given equal status to males during learning tasks (Chiu, Chiu, Chiu, & Chiu, 2002). Outside of the classroom, Seymour and Hewitt (1997) found that female engineering students were more likely to integrate themselves socially by joining clubs and social networks.

The aforementioned findings regarding collaboration in engineering education and, more specifically, collaboration among female engineering students provided the basis for this research. The purpose of our first study was to examine the combined effects of students' reported use of collaborative learning strategies and self-efficacy on undergraduate engineering students' achievement. Additionally, we examined the relationships between engineering students' self-reported collaboration, self-efficacy, knowledge building activities, and teacher directedness. By using self-report as a data collection method, we were able to gain information from the students' unique perspective rather than from that of the course instructors. Our specific research questions were as follows: (1) What is the relationship between engineering students' reported use of collaborative learning strategies, self-efficacy, use of knowledge building behaviors, and teacher directedness?, and (2) Does reported use of collaborative learning strategies predict students' academic performance? Based on the existing literature and research, we hypothesized that students' reported collaborative learning strategies would be significantly associated with their reported knowledge building activities (Husman et al., 2007; Scardamalia & Bereiter, 1991), self-efficacy (Moriarty et al., 1995), teacher directedness (Stump et al., 2008), and course grade (Hake, 1998; Prince, 2004; Shell et al., 2005), and that students' reported collaboration would significantly predict course grade over and above self-efficacy as well as other measures of constructivist learning.

METHOD—STUDY 1

Participants

Participants were recruited from Mechanical and Aerospace Engineering (MAE) courses at a large public university in the southwestern United States. The students were enrolled in eight different courses: two 200 Level courses (n = 60); five 300 Level courses (n = 74); and one 400 Level course (n = 16). Fifty-five percent of the students who completed these courses participated in the survey. Because students were taking multiple MAE courses and surveys were course specific, they had the opportunity to take multiple surveys. To reduce the number of surveys to one per participant when duplicates occurred, we retained only the survey from the highest-level course. This process resulted in 150 unique participants for our analysis. The participant age range was 18 to 44 years, with a mean age of 22.7 years. Participants reported their ethnicity as White (72%), Asian (10%), Black (< 2%), Hispanic (5%), and Native American (< 2%). Female students comprised 21.3% of the sample. The sample contained 8% more White, 7% fewer Black, and 3% fewer Hispanic students than the ethnic breakdown of those receiving science and engineering degrees across the United States in 2007 (NSF, 2010). Comparison of grade distribution between the study sample and all engineering students in the eight surveyed courses revealed that grade distributions were similar between both groups: 32% of the sample received "A's," 41% received "B's," and 27% received a "C or lower," whereas 28% of all students in surveyed courses received "A's," 41% received "B's," and 31% received a "C or lower."

Data Collection Procedure

In the spring semester of 2007, our research team surveyed students in the aforementioned post-secondary engineering courses. Participation in the study was voluntary and students were offered a small cash award as an incentive. The survey was administered in one of two formats: a pencil and paper version that was completed in-person during class, or an online version that was completed outside of class. Following course completion, students' final grades were retrieved via the university registrar's office.

Measures

Student Perceptions of Classroom Knowledge-building (SPOCK). The SPOCK subscales (Shell et al., 2005) are established measures of student study strategies (see Shell et al., 1997; Shell et al., 1995 for full data on instrument development and psychometric properties) that have provided reliability evidence within samples of engineering students (Husman et al., 2007). We utilized three SPOCK subscales to assess students' perceptions: The eight-item *knowledge-building* subscale assessed students' tendencies to construct their own understanding of classroom material. Examples of knowledge-building items are "Whenever I learn something new in this class, I try to tie it to other facts and ideas that I already know," and "I try to go beyond what we are given in the lectures and text." The four-item *teacher directedness* subscale assessed the extent of teacher guidance in classroom activities. Examples of items from this subscale are "In this class, the instructor focuses on getting us to learn the right answers to questions," and "In this class, the instructor tells us what the right answers are." The five-item *collaborative learning* subscale assessed informal student interaction with their peers. The content evaluated by these items (see Table 1) reflects a social constructivist school of thought, which maintains that knowledge is co-constructed between learners (Driscoll, 2005). For each of the SPOCK subscale items, the students responded on a Likert-type scale ranging from 1 (*almost never*) to 5 (*almost always*). The SPOCK subscales did not assess the professors' instructional strategies but rather student perceptions about learning course material. Students were instructed to think only about the course they were being surveyed in when responding to the subscale items.

Motivated Strategies for Learning Questionnaire (MSLQ). The MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1993) is an established scale utilized to evaluate students' motivation behaviors and their use of different study strategies. Only the eight-item subscale related to *self-efficacy* for learning course material was administered to participants of this study. Example items from this subscale are, "I'm confident I can understand the basic concepts taught in this class," and "I am certain I can master the skills being taught in this course." The students responded on a Likert-type scale ranging from 1 (*not at all true of me*)

TABLE 1
Informal Collaborative Learning Practices Measured in the SPOCK Collaboration Subscale

Subscale Items
1. … my classmates and I actively work together to complete assignments
2. … my classmates and I actively work together to help each other understand the material
3. … I get helpful comments about my work from other students
4. … my classmates and I actively work together to learn new things
5. … my classmates and I actively share ideas

to 7 (*very true of me*). Students were instructed to consider only the course they were being surveyed in when responding to the items.

Course grade. Students' grades for the course in which they were surveyed were retrieved from the university registrar's office and included in the data set. The grades were measured on a 4 point plus/minus grading system; the highest possible grade was an A+ (4.333) and the lowest possible grade was an E (0.000).

Analysis

To maintain the statistical assumption of independence, we eliminated extra surveys from students who took the survey in more than one of the eight surveyed courses. In these situations, we retained only the survey from their highest-level course. We used listwise deletion for missing values in the dataset. For each student, we created subscale scores for collaboration, knowledge building, teacher directedness, and self-efficacy by calculating a mean score from the related survey items. Coefficient alpha (Cronbach, 1951) was computed on each subscale to obtain reliability evidence. All subscale scores as well as scores for course grade were then converted to z-scores (Coladarci, Cobb, Minium, & Clarke, 2004) to preserve students' within-group position but remove mean differences between courses that may have occurred due to dissimilarities in instructor approach. Descriptive statistics for all variable subscales were computed and analyzed, and a bivariate correlation matrix was constructed to examine the relationship between the variables (Cohen, Cohen, West, & Aiken, 2003). Multiple regression analysis was then used to evaluate the predictive power of the linear combination of collaboration, self-efficacy, knowledge building, and teacher directedness on course grade. Based on the results of this analysis, a hierarchical multiple regression analysis was conducted to evaluate the contribution of self-efficacy and collaborative learning to the variance in course grade.

RESULTS—STUDY 1

Descriptive statistics for our variables of interest are displayed in Table 2. Coefficient alphas (Cronbach, 1951) for the subscales were as follows: Collaboration = .94, Knowledge building = .83, Teacher directedness = .60, and Self-efficacy = .92. The bivariate correlation matrix indicated significant positive relationships between collaborative learning and self-efficacy, knowledge building, and course grade (see Table 3). In addition to the positive relationship with collaborative learning, self-efficacy was positively related to knowledge building, teacher directedness, and course grade. Teacher directedness was not significantly related to knowledge building, collaboration, or course grade. Knowledge building was not significantly related to teacher directedness or course grade. Multiple regression analysis showed that the linear combination of the predictor variables-self-efficacy, collaboration, knowledge building, and teacher directedness-significantly predicted course grade, $F(4,145) = 12.32, p < .01$, adj. $R^2 = .23$; however, knowledge building, and teacher directedness did not significantly explain the variance. The model was re-specified and the linear combination of self-efficacy and collaboration was significantly predictive of course grade, $F(2, 147) = 23.65, p < .01$, adj. $R^2 = .23$. Collaborative learning, $t(148) = 3.15$, $p < .01$, was a significant predictor of course grade over and above self-efficacy, $t(148) = 5.41, p < .01$; collaboration accounted for an additional 5% of the variance in students' grades, $R^2\,\Delta = .05$, $F\Delta\,(1, 147) = 9.92, p < .01$, indicating that students with similar levels of self-efficacy were more likely to

TABLE 2
Descriptive Statistics (z Scores) for all Variables of Interest (N = 150)

	Min	Max	*M*	*SD*
Knowledge Building (SPOCK)	−2.35	2.48	0.00	0.98
Teacher Directedness (SPOCK)	−2.73	2.04	0.00	0.98
Collaboration (SPOCK)	−2.51	1.62	0.00	0.98
Self-efficacy (MSLQ)	−2.67	2.14	0.00	0.98
Course Grade	−3.19	1.82	0.00	0.98

TABLE 3
Correlations Among all Variables of Interest (N = 150)

	1	2	3	4	5
1. Knowledge Building (SPOCK)	—				
2. Teacher Directedness (SPOCK)	.15	—			
3. Collaborative Learning (SPOCK)	.19*	.01	—		
4. Self-Efficacy (MSLQ)	.26**	.20*	.19*	—	
5. Course Grade	.09	.00	.31**	.44**	—

Note. * = $p < .05$; ** = $p < .01$.

have higher course grades if they also engaged in collaborative learning interactions with their peers (see Table 4).

DISCUSSION—STUDY 1

The results of study 1 suggested that collaboration was a significant predictor of students' academic performance in the engineering learning setting. Students who reported engaging in collaborative learning also reported high self-efficacy for learning the course content. However, regardless of their levels of self-efficacy, students who reportedly engaged in collaborative learning-working together with peers to complete assignments, discuss new material, or share ideas—also performed better in terms of grades than those who reported working independently.

Additionally, the results of this study highlighted the importance of the relationships among collaborative learning, student knowledge building behaviors, teacher directedness, and self-efficacy. In our sample, collaborative learning was positively correlated to knowledge building; students who more often engaged in collaborative learning with their peers were also those who tended to construct their own understanding of the learning materials given. Collaboration and knowledge building were also significantly positively associated with self-efficacy, supporting our argument that constructivist learning strategies are

TABLE 4
Summary of Hierarchical Regression Analysis for Variables Predicting Academic Achievement (N = 150)

Model/Predictor Variable	*Model* R^2	$R^2_{adj.}$	B (SEB)	β	sr^2
Model 1	0.25	0.23*			
Intercept			1.11 (0.07)		
Self-efficacy			0.43 (0.08)	0.43*	0.16
Collaboration			0.24 (0.07)	0.24*	0.05
Knowledge Building			-0.06 (0.08)	-0.06	0.00
Teacher Directedness			-0.08 (0.07)	-0.08	0.01
Model 2	0.24	0.23*			
Intercept			1.07 (0.07)		
Self-efficacy			0.40 (0.07)	0.40*	0.15
Collaboration			0.23 (0.07)	0.23*	0.05

Note. $*p < .01$

associated with student confidence in their ability to learn course material. Students' perceptions of teacher directedness were positively associated with their reported self-efficacy, revealing that students' impressions of teacher support also bear relationship to confidence in their ability to learn course material. However, it is important to note that in our results, teacher directness and knowledge building were not significant predictors of students' achievement as measured by course grades.

Following these results, we initiated a more specific investigation of the influence of gender on engineering students' motivation and learning strategies. Our second study extended the scope of this research to include examination of gender differences in engineering programs; more specifically, we explored the relationship between student achievement, self-efficacy, and collaborative learning strategies with regard to gender. Because our first study showed no predictive ability of knowledge building and teacher directedness on achievement, we omitted those variables from our second study.

Our specific research questions for the second study were as follows: (1) Does the relationship between reported use of collaborative learning strategies, self-efficacy, and course grade differ between male and female engineering students?, and (2) Are there differences in reported use of collaborative learning strategies between male and female engineering students who earn higher course grades? Based on the existing literature (e.g., Huang et al., 2000; Vogt et al., 2007), we hypothesized that there would be no difference between males and females in their reported self-efficacy or their achievement in engineering courses. We hypothesized that females would be more interested in collaborating with other students to learn course content (Seymour & Hewitt, 1997). Lastly, due to the competitive atmosphere in the engineering course environment, we hypothesized that students of either gender with higher grades in the course would report less engagement in peer learning (e.g., Guzdial et al., 2001) than those with lower grades.

As recommended by Glasser and Smith (2008), we first operationalized the term gender. In the context of our research, we used gender to refer to the social role assumed by the participants. This information was obtained from the university registrar, which came from students' self-reported information.

METHOD—STUDY 2

Participants

Participants were recruited from 14 Mechanical and Aerospace Engineering (MAE) courses at the same southwestern university; the sample represented 51.6% of all the students who completed the 14 courses. Because students were taking multiple MAE courses and surveys were course specific, they had the opportunity to take multiple surveys. To reduce the number of surveys to one per participant when duplicates occurred, we retained only the survey from the highest-level course. This process resulted in 513 unique participants for our analysis. Our sample contained 429 male students and 84 female students. The average year in school for female students was second semester of junior year; for male students, it was first semester of junior year. The sample reflected numbers of male and female students in the general engineering student population (Snyder & Dillow, 2010). The mean age and cumulative grade point average were similar between male and female students, but ethnicity and course grade distribution for the course in which they were surveyed differed between the two groups (see Table 5). The ethnicity of our combined sample also differed slightly from those who receive science and engineering degrees nationally (NSF, 2010) in that our sample contained 6% fewer Blacks, 4% more Hispanics, and 8% more Whites. Further comparison of grade distribution between our combined male and female sample ($N = 513$) and all engineering students who completed the surveyed courses ($N = 1{,}558$) revealed that grade distributions differed slightly between the sample and all students in surveyed courses. For the sample, 33% received "A's," 32% received "B's," and 35% received a "C or lower"; in all engineering students who completed surveyed courses, 29% received "A's," 36% received "B's," and 35% received a "C or lower."

Data Collection Procedure

For this study, participants were surveyed each semester from Fall 2006 through Fall 2007; surveys were again administered in an online or in-person format, dependent upon the preferences of the course instructors. All participants in this study also received a small cash incentive for their participation. Students' course grades were retrieved from the university registrar after the semester ended.

Measures

Student Perceptions of Classroom Knowledge-building (SPOCK; Shell et al., 2005). In this study, we utilized only the *collaborative learning* subscale (see Table 1) to assess students' perceived engagement in collaboration. As in study 1, students were instructed to think only about the course in which they were surveyed when responding to the subscale items.

Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1993). Only the subscale related to *self-efficacy* for learning course material was administered to participants of this study. As in study 1, students were instructed to think only about the course in which they were surveyed when responding to the self-efficacy subscale items.

TABLE 5
Demographics of Sample

	Male Sample $n = 429$	Female Sample $n = 84$
Ethnicity		
Asian/Pacific Islander	32(8%)	12(14%)
White	319(74%)	48(57%)
Hispanic	43(10%)	16(19%)
Other/not reported	35(8%)	8(10%)
Age		
Minimum	18	18
Maximum	50	30
Mean	21	21
Cumulative Grade Point Average		
Minimum	0.00	2.08
Maximum	4.18	4.33
Mean	3.13	3.36
Course Grade Distribution		
A	139(32%)	32(38%)
B	141(33%)	24(29%)
C or lower	149(35%)	28(33%)

Course grade. Students' grades for the course in which they were surveyed were retrieved from the university registrars office. Students were grouped into three grade groups: A, B, and C or below.

Analysis

To maintain the statistical assumption of independence, we eliminated extra surveys from students who took the survey in more than one of the 14 surveyed courses. In these situations, we retained only the survey from their highest-level course. We used listwise deletion for missing values in the dataset. Descriptive statistics were calculated by gender and also by gender and grade group for collaboration, self-efficacy, and course grade. Coefficient alpha (Cronbach, 1951) was computed on each subscale to obtain reliability evidence. A two-way multivariate analysis of variance, or MANOVA (Maxwell & Delaney, 2004), was conducted to explore the effect of gender and grade group (A, B, C or lower) on students' confidence about learning in the course and reported use of collaboration strategies. Due to unequal numbers of male and female participants, a weighted means approach was used for the analysis. According to Maxwell and Delaney (2004), weighted means are appropriately used in MANOVA when differences in cell sizes are believed to represent differences in the population. As indicated previously, the number of female students in our sample is reflective of the female engineering student population across the nation.

RESULTS—STUDY 2

Descriptive statistics for our variables of interest are displayed in Tables 6 and 7. The coefficient alpha (Cronbach, 1951) was 0.91 for the collaboration subscale and 0.92 for the self-efficacy subscale. Exploration of the data revealed mean differences between female students' and male students' reported use of collaboration strategies as well as grade group mean differences in reported collaboration strategy use. Although differences between grade groups' self-efficacy were apparent, the mean difference between male and female students' self-efficacy was subtle.

Within the MANOVA model conducted to explore mean differences, no serious violations of assumptions pertaining to independence of observations, multivariate normality, or homogeneity of covariance matrices were noted. At the multivariate level, significant differences were found for the effect of gender, Wilks's $\Lambda = .98$, $F(2{,}506) = 4.18$, $p = .02$, partial $\eta^2 = .02$, and course grade group, Wilks's $\Lambda = .78$, $F(4{,}1012) = 33.05$, $p < .01$, partial $\eta^2 = .12$ on the dependent variables (reported collaboration use and self-efficacy). The interaction between gender and course grade was not significant, Wilks's $\Lambda = 1.00$, $F(4, 1012) = .55$, $p = .70$. At the univariate level, significant differences were found between course grade groups for reported self-efficacy and collaboration use [Self-efficacy: $F(2{,}507) = 57.20$, $p < .01$, partial $\eta^2 = .18$; Collaboration: $F(2{,}507) = 10.96$, $p < .01$, partial $\eta^2 = .04$]. For the gender group however, only use of collaboration strategies was significantly different [Collaboration: $F(1{,}507) = 7.00$, $p < .01$, partial $\eta^2 = .01$; Self-efficacy: $F(1{,}507) = 1.50$, $p = .22$, partial $\eta^2 < .01$]. Post hoc analysis of the grade groups using Tukey's HSD revealed that "B" students reported significantly higher collaborative strategy use than "A" students ($p < .01$) or "C or below" students ($p < .01$). Additionally all three grade groups were significantly different in their self-efficacy perceptions ($p < .05$).

TABLE 6
Descriptive Statistics for all Variables by Gender

	Min	Max	*M*	*SD*	Skew
Female Students ($n = 84$)					
Collaboration	1.00	5.00	3.45	1.15	−0.58
Self-efficacy	1.75	7.00	5.13	0.95	−0.41
Course Grade	0.00	4.33	2.99	1.06	−0.82
Male Students ($n = 429$)					
Collaboration	1.00	5.00	3.12	1.08	−0.28
Self-efficacy	1.00	7.00	5.27	1.11	−0.59
Course Grade	0.00	4.33	2.78	1.15	−0.81

TABLE 7
Descriptive Statistics by Grade Group

	Course Grade	*n*	Min	Max	*M*	*SD*	Var
			Collaboration				
Female Students	A	32	1.00	5.00	3.24	1.30	1.70
	B	24	2.60	4.80	3.79	0.78	0.61
	C or Below	28	1.00	5.00	3.41	1.19	1.41
Male Students	A	139	1.00	5.00	3.05	1.05	1.10
	B	141	1.00	5.00	3.43	0.93	0.87
	C or Below	149	1.00	5.00	2.89	1.16	1.35
All Students	A	171	1.00	5.00	3.08	1.10	1.21
	B	165	1.00	5.00	3.49	0.92	0.85
	C or Below	177	1.00	5.00	2.97	1.18	1.39
			Self-Efficacy				
Female Students	A	32	4.00	7.00	5.61	0.69	0.47
	B	24	3.38	6.75	5.12	0.88	0.78
	C or Below	28	1.75	7.00	4.58	1.01	1.01
Male Students	A	139	3.00	7.00	5.74	0.93	0.87
	B	141	1.13	7.00	5.47	0.96	0.92
	C or Below	149	1.00	7.00	4.64	1.11	1.23
All Students	A	171	3.00	7.00	5.72	0.89	0.79
	B	165	1.13	7.00	5.42	0.95	0.91
	C or Below	177	1.00	7.00	4.63	1.09	1.19

DISCUSSION—STUDY 2

The results of this study provide additional evidence for the improved academic status of females in engineering courses. Our findings suggest that although still underrepresented, women enrolled in engineering courses are not statistically different from their male counterparts in achievement (course grade) or perceptions of their competence (self-efficacy).

Additionally, our results suggest that by self-report, female students engage in significantly more collaboration than male students when learning course content. These findings mirror those of Seymour and Hewitt (1997), suggesting that female students taking mechanical and aerospace engineering courses do seem to be seeking and finding collaborative learning opportunities and support, despite more traditional course structures.

Although women did report engaging in more collaborative learning than their male counterparts across grade groups, the pattern of women and men's collaboration in relation to their course grade remained consistent, and women fared no better than men academically as a result of their collaboration. More specifically, all students who received "B's" as their final course grade used more collaborative learning strategies than all students who received "A's" or "C's" or lower. Previous research on collaborative learning led us to expect that students who engaged in these strategies would be more academically successful than those who did not (Bowen, 2000; Hake, 1998; Prince, 2004; Springer et al., 1999; Smith et al., 2009). In this study there was, in fact, a curvilinear relationship between student performance and their strategy use. Perhaps, as noted in previous studies (Guzdial et al., 2001), the faculty practice of grading on a curve did decrease confident students' willingness to collaborate; however, students who were less confident about their knowledge may have been more willing than their peers to seek help to improve their performance.

Eliminating male-normed, hierarchically structured engineering courses has been a goal for many involved in engineering education (e. g., Sadker & Sadker, 1994; Vogt et al., 2007). However, our findings may reflect a continuation of the competitive atmosphere reportedly common in engineering courses in the U.S. Although the most confident students are less willing than their peers to collaborate, our data does indicate that most students do, to some extent, work with peers, even in these competitive evaluation environments. Given this, even if faculty are unable to change their grading practices, they could still provide support for collaboration which could increase students' existing efforts to engage in this effective strategy.

Limitations, Implications, and Future Directions

A limitation of our studies is that our samples do not match the general engineering student population with respect to ethnicity. This would limit generalization of our findings to engineering student groups with similar ethnic composition. Another limitation is that our data was self-reported by students and we did not have access to information regarding the nature of their collaborative activities or the role they assumed. Despite these limitations however, our results show a positive relationship between collaborative learning, confidence, and academic achievement, giving preliminary evidence to suggest that in the engineering learning environment, increasing opportunities for collaborative learning may be beneficial.

It is important to note that the collaboration examined in each of our studies was not a formal structured part of the curriculum. Our survey items addressed student perceptions of collaboration that occurred informally, e.g., brief in-class peer discussion, study groups, conversations after class, and similar activities. Our findings regarding the success of informal collaboration have significant implications for faculty who may not be inclined to use formal collaborative learning activities in their classroom. Whereas formal collaborative learning activities may mandate a restructuring of the syllabus or at minimum, a reorganization of class time, informal collaborative activities can easily be incorporated into a traditional instructional format. Moreover, with the advent of real-time assessment techniques, researchers (see Smith, Sheppard, Johnson, & Johnson, 2005 for discussion) suggest that need for interaction between students can be determined using the responses given to instructors' questions during a lecture. For example, if the class offers a mixture of correct and incorrect responses to an instructor's question during lecture, the instructor may have students turn to their neighbor, compare answers, justify their response, and attempt to reach consensus (Smith et al., 2005). This interaction at strategic points in the lecture will not only keep students engaged, but periodic comprehension checks and resultant collaboration may serve to eliminate student confusion which can lead to feelings of being 'lost' during class.

Additionally, students' perceived value of informal collaboration as a strategy to improve learning may influence its use. When used informally to problem solve, or as a help-seeking / help-giving behavior, students may view collaboration as more palatable than structured group work, where the complexities of group dynamics can take precedence over knowledge building activities (Salomon & Globerson, 1989). Ultimately, informal collaboration may be more beneficial simply because students initiate it and thus they feel empowered to influence their own learning. Future studies should examine ways to cultivate or extend the informal networks of peer support these students seem to be developing.

As previously noted however, students may be less willing to collaborate with their peers when working on problems that appear to be a competitive pursuit toward a single answer. Cohen (1994) recommends the use of ill-structured or open-ended problems to encourage active collaborative discussion and learning by students. Additional challenges are presented for engineering faculty to create these types of opportunities for collaboration in the classroom by providing complex problems to solve that require cooperative, divergent thinking.

Our results showed that the greater reported collaboration by female students was not significantly associated with higher grades than their male counterparts. Beyond effects on academic achievement however, it may be more important to consider the value of collaboration as a learning strategy that has high appeal to female engineering students. Previous work has shown that female engineering students perceived less opportunity to collaborate with peers in male normed classrooms and complained of being excluded from predominantly male study groups (Seymour & Hewitt, 1997). Other work has shown that female engineering students seek collaborative and social activities outside of their coursework as a means to maintain self-efficacy despite perceived inequity in the classroom (Vogt et al., 2007); our current study results indicate that in engineering coursework, female students choose to collaborate more often than male students. Clearly, this population has a need for affiliation with their peers. Supporting this need may be another way to encourage their academic success. Academic achievement in the early semesters of the engineering curriculum has been linked to retention for both genders (Jackson, Gardner, & Sullivan, 1993); the results of this study call out the need for further research on the role that collaborative learning may play in the support of engineering students' achievement and retention.

Another limitation of our study is that faculty instructional and grading practices of the different engineering courses may have influenced the nature and frequency of students' collaborative learning as well as evaluation of their achievement. Future studies should strive to examine both institutional and instructional practices that may facilitate or inhibit students' collaboration. This could be accomplished through observation and analytic techniques that examine nested data structures, such as hierarchical linear modeling (Raudenbush & Byrk, 2002). Future studies should also more fully describe the mix, or composition of collaborative groups and the interaction that takes place during informal collaboration of engineering students as well as describe other effects that collaboration may have on the cognitive and social aspects of learning. Higher order thinking that is attained by engaging in high-level discourse may be an outcome of collaboration not reflected in students' course grades. Cooperativeness and friendliness among peers may be an outcome of collaborative activities that also serves to improve retention of students in the engineering curriculum. Anecdotal evidence from Seymour and Hewitt's (1997) work supports the idea that emotional support gained from collaborative activities with peers is significant to the survival of students in science and engineering programs. Further research should continue to delineate and measure these important benefits of collaborative learning strategies used among peers.

Acknowledgments

Funding for the current study was provided by National Science Foundation Grant, REC-0546856, *CAREER: Connecting with the Future: Supporting Career and Identity Development in Post-Secondary Science and Engineering*. A portion of this material has been presented and published as Proceedings from the Frontiers in Education Annual Meeting, held in Saratoga Springs, New York in 2008, and another portion of this material has been presented at the Annual Meeting of the International Conference on Motivation, held in Turku, Finland in August 2008. No copyrighted material from other sources has been used or adapted.

The authors would like to thank the anonymous reviewers for their comprehensive and thoughtful commentary on this article prior to revisions.

References

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Bandura, A., & Locke, E. A. (2003). Negative self-efficacy and goal effects revisited. *Journal of Applied Psychology, 88*(1), 87–99.

Barbieri, M. S., & Light, P. H. (1992). Interaction, gender, and performance on a computer-based problem solving task. *Learning and Instruction, 2*(3), 199–213.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307–359.

Bowen, C. W. (2000). A quantitative literature review of cooperative learning effects on high school and college achievement. *Journal of Chemical Education, 77*(1), 116–119.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching, 43*(5), 485–499.

Chi, M. T. H., Siler, S. A., Jeong, H., Yamauchi, T., & Hausmann. R. G. (2001). Learning from human tutoring. *Cognitive Science, 25*(4), 471–533.

Chiu, L. H., Chiu, S. Y. J., Chiu, H., & Chiu, D. M. (2002). Engineering and technology education for women in the new century. *Engineering Science and Education Journal, 11*(4), 145–152.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64*(1), 1–35.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression / correlation analysis for the behavioral sciences*. Mahwah, NJ: Lawrence Erlbaum Assoc.

Coladarci, T., Cobb, C. D., Minium, E. W., & Clarke. R. B.(2004). *Fundamentals of statistical reasoning in education*. Hoboken, NJ: John Wiley & Sons, Inc.

Covington, M. V. (2000). Goal theory, motivation, and school achievement: An integrative review. *Annual Review Psychology, 51*, 171–200.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334.

Driscoll, M. P. (2005). *Psychology of learning for instruction*, 3rd ed. Boston, MA: Pearson Education, Inc.

Duderstadt, J. J. (2008). Engineering for a changing world: A roadmap to the future of engineering practice, research, and education. *The Millenium Project*. Ann Arbor, MI: The University of Michigan.

Felder, R. M., & Brent, R. (2005). Understanding student differences. *Journal of Engineering Education, 94*(1), 57–72.

Fletcher, B. (1985). Group and individual learning of junior school children on a microcomputer-based task: Social or cognitive facilitation? *Educational Review, 37*(3), 251–261.

French, B. F., Immekus, J. C., & Oakes, W. C. (2005). An examination of indicators of engineering students' success and persistence. *Journal of Engineering Education, 94*(4), 419–425.

Fuchs, L. S., Fuchs, D., Kazdan, S., Karn, K., Calhoon, M. B., Hamlett, C. L., & Hewlett, S. (2000). Effects of workgroup structure and size on student productivity during collaborative work on complex tasks. *Elementary School Journal, 100*(3), 183–212.

Gillies, R. M., & Ashman, A. F. (1995). The effects of gender and ability on students' behaviours and interactions in classroom-based work groups. *British Journal of Educational Psychology, 65*(2), 211–225.

Glasser, H. M., & Smith, J. P. (2008). On the vague meaning of "gender" in education research: The problem, its sources, and recommendations for practice. *Educational Researcher, 37*(6), 343–350.

Guzdial, M., Ludovice, P., Realff, M., Morley, T., Carroll, K., & Ladak, A. (2001, October). The challenge of collaborative learning in engineering and math. *Proceedings of Frontiers in Education Conference, Reno, NV.*

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74.

Heywood, J. (2008, October). Philosophy and engineering education: A review of certain developments in the field. *Proceedings of the Frontiers in Education Conference, Saratoga Springs, NY.*

Howe, C. (2009). Collaborative group work in middle childhood: Joint construction, unresolved contradiction, and the growth of knowledge. *Human Development, 52*(4), 215–239.

Huang, G, Taddese, N., Walter, E., & Peng, S. S. (2000). *Entry and persistence of women and minorities in college science and engineering education*. Publication Number: NCES 2000601. Washington, DC: National Center for Educational Statistics.

Husman, J., Lynch, C., Hilpert, J., & Duggan, M. (2007, June). *Validating measures of future time perspective for engineering students: Steps toward improving engineering education.* Paper presented at the American Society for Engineering Education Annual Conference and Exposition, Honolulu, HI.

Jackson, L. A., Gardner, P. D., & Sullivan, L. A. (1993). Engineering persistence: Past, present, and future factors and gender differences. *Higher Education, 26*(2), 227–246.

Jeong, H., & Chi, M. T. H. (2007). Knowledge convergence and collaborative learning. *Instructional Science, 35*(4), 287–315.

Johnson, D., Johnson, R., & Smith, K. (1998a). *Active learning: Cooperation in the college classroom*, 2nd ed. Edina, MN: Interaction Book Co.

Johnson, D., Johnson, R., & Smith, K. (1998b). Cooperative learning returns to college: What evidence is there that it works? *Change, 30*(4), 26–35.

Kalonji, G. (2005). Capturing the imagination: High-priority reforms for engineering educators. In National Academy of Engineering (Ed.), *Educating the engineer of 2020: Adapting engineering education to the new century* (pp. 146–150). Washington, DC: National Academies Press.

Karabenick, S. A. (2004). Perceived achievement goal structure and college student help seeking. *Journal of Educational Psychology, 96*(3), 569–581.

Linnenbrink, E. A., & Pintrich, P. R. (2003). The role of self-efficacy beliefs in student engagement and learning in the classroom. *Reading and Writing Quarterly, 19*(2), 119–137.

Mason, L. (1998). Sharing cognition to construct scientific knowledge in school context: The role of oral and written discourse. *Instructional Science, 26*(5), 359–389.

Maxwell, S. E., & Delaney, H. D. (2004). *Designing experiments and analyzing data: A model comparison perspective*, 2nd ed. Mahwah, NJ: Lawrence Erlbaum Associates.

McCaslin, M., & Good, T. L. (1992). Compliant cognition: The misalignment of management and instructional goals in current school reform. *Educational Researcher, 21*(3), 4–17.

Mercer, N. (1996). The quality of talk in children's collaborative activity in the classroom. *Learning and Instruction, 6*(4), 359–377.

Moriarty, B., Douglas, G., Punch, K. & Hattie, J. (1995). The importance of self-efficacy as a mediating variable between learning environments and achievement. *British Journal of Educational Psychology, 65*(1), 73–84.

National Science Foundation. (2010, March). *Science and engineering indicators 2010*. Retrieved from http://www.nsf.gov/statistics/seind10/

O'Donnell, A. M., & O'Kelly, J. (1994). Learning from peers: Beyond the rhetoric of positive results. *Educational Psychology Review, 6*(4), 321–349.

Oshima, J., Scardamalia, M. & Bereiter, C. (1996). Collaborative learning processes associated with high and low conceptual progress. *Instructional Science, 24*(2), 125–155.

Piaget, J. (1926). *The language and thought of a child*. New York, NY: Routledge.

Pintrich, P. R., Smith, D.A., Garcia, T. & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational & Psychological Measurement, 53*(3), 801–813.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231.

Raudenbush, S. W., & Byrk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*, 2nd ed.Thousand Oaks, CA: Sage Publications Inc.

Ryan, A. M., Patrick, H., & Shim, S. O. (2005). Differential profiles of students identified by their teacher as having avoidant, appropriate, or dependent help-seeking tendencies in the classroom. *Journal of Educational Psychology, 97*(2), 275–285.

Sadker, M., & Sadker, D. (1994). *Failing at fairness: How America's schools cheat girls*. New York, NY: C. Scribner & Sons.

Salomon, G., & Globerson, T. (1989). When teams do not function the way they ought to. *International Journal of Educational Research, 13*(1), 89–99.

Savicki, V., Kelley, M. & Lingenfelter, D. (1996). Gender and group composition in small task groups using computer-mediated communication. *Computers in Human Behavior, 12*(2), 209–224.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *The Journal of the Learning Sciences, 1*(1), 37–68.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences, 3*(3), 265–283.

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview.

Shell, D. F., Husman, J. E., Cliffel, D., Nath, I., Sweany, N., & Turner, J. (1997). *Project CIRCLE: Second year evaluation report* (Grant #R215D30195). Washington, DC: U.S. Department of Education: Secretary's Fund for Innovation in Education and The University of Texas, College of Education, Learning Technology Center.

Shell, D. F., Husman, J. E., Droesch, D. M., Nath, I., Wall, N., & Turner, J. (1995). *Project CIRCLE: First year evaluation report* (Grant #R215D30195). Washington, DC: U.S. Department of Education: Secretary's Fund for Innovation in Education and University of Texas, College of Education, Learning Technology Center.

Shell, D. F., Husman, J., Turner, J. E., Cliffel, D. M., Nath, I., & Sweany, N. (2005). The impact of computer supported collaborative learning communities on high school students' knowledge building, strategic learning, and perceptions of the classroom. *Journal of Educational Computing Research, 33*(3), 327–349.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology, 21*(1), 43–69.

Smith, B. L., & MacGregor, J. T. (1992). What is collaborative learning? In A. S. Goodsell, M. R. Maher, & V. Tinto (Eds.), *Collaborative learning: A sourcebook for higher education*. University Park, PA: National Center on Postsecondary Teaching, Learning, & Assessment.

Smith, K. A., Sheppard, S. D., Johnson, D. W. & Johnson, R. T. (2005). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education, 94*(1), 87–101.

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science, 323*(5910), 122–124.

Snyder, T. D., & Dillow, S. A. (2010). *Digest of education statistics 2009* (NCES 2010-013). National Center for Education Statistics, Institute of Education Sciences, Washington, DC: U.S. Department of Education.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research, 69*(1), 21–51.

Stump, G., Hilpert, J., & Husman, J. (2008). *Freshman students' waning beliefs about math and science: Do directive instructors and academic success courses help*? Poster session presented at the annual meeting of the American Educational Research Association, New York, NY.

Summers, J. J., Bergin, D. A., & Cole, J. S. (2009). Examining the relationships among collaborative learning, autonomy support, and student incivility in undergraduate classrooms. *Learning and Individual Differences, 19*(2), 293–298.

Turner, J. C., Midgley, C., Meyer, D. K., Gheen, M., Anderman, E. M., Kang, Y., & Patrick, H. (2002). The classroom environment and students' reports of avoidance strategies in mathematics: A multimethod study. *Journal of Educational Psychology, 94*(1), 88–106.

Van Boxtel, C., Van der Linden, J., & Kanselaar, G. (2000). Collaborative learning tasks and the elaboration of conceptual knowledge. *Learning and Instruction, 10*(4), 311–330.

Vogt, C. M., Hocevar, D., & Hagedorn, L. S. (2007). A social cognitive construct validation: Determining women and men's success in engineering programs. *The Journal of Higher Education, 78*(3), 337–364.

Volet, S., Summers, M., & Thurman, J. (2009). High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? *Learning and Instruction, 19*(2), 128–143.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.). Cambridge, MA: Harvard University Press.

Webb, N. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research, 13*(1), 21–39.

Webb, N. M., & Mastergeorge, A. (2003). Promoting effective helping behavior in peer-directed groups. *International Journal of Education Research, 39*(1–2), 73–97.

Webb, N. M., Nemer, K. M., Chizhik, A. W., & Sugrue, B. (1998). Equity issues in collaborative group assessment: Group composition and performance. *American Educational Research Journal, 35*(4), 607–651.

Webb, N., & Palincsar, A. (1996). Group processes in the classroom. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology*, 1st ed. New York, NY: Simon and Schuster.

Webb, N. M., Troper, J. D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology, 87*(3), 406–423.

Weinstein, C. E., Husman, J., & Dierking, D. R. (2000). Interventions with a focus on learning strategies. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 727–747). San Diego, CA: Academic Press.

Wiley, J., & Bailey, J. (2006). Effects of collaboration and argumentation on learning from web pages. In A. M. O'Donnell, C. E. Hmelo-Silver, & G. Erkens (Eds.), *Collaborative learning, reasoning, and technology* (pp. 297–321). Mahwah, NJ: Lawrence Erlbaum Assoc.

Wood, W. (1987). Meta-analytic review of sex differences in group performance. *Psychological Bulletin, 102*(1), 53–71.

Zhang, G., Anderson, T., Ohland, M. W., & Thorndyke, B. (2004). Identifying factors influencing engineering student graduation: A longitudinal and cross-institutional study. *Journal of Engineering Education, 93*(4), 313–320.

Authors

Glenda Stump is a post-doctoral scholar in the School of Social and Family Dynamics at Arizona State University, PO Box 3701, Tempe, AZ 85287-3701; glenda.stump@asu.edu.

Jonathan Hilpert is an assistant professor of Educational Studies at Indiana University - Purdue University Fort Wayne, 2101 E. Coliseum Blvd. Fort Wayne, IN 46805-1499; hilpertj@ipfw.edu.

Jenefer Husman is an associate professor in the School of Social and Family Dynamics at Arizona State University, PO Box 3701, Tempe, AZ 85287-3701; jenefer.husman@asu.edu.

Wen-Ting Chung is a doctoral student in Educational Psychology at Arizona State University, PO Box 3701, Tempe, AZ 85287-3701; wen-ting.chung@asu.edu.

Wonsik Kim is a doctoral student in Educational Psychology at Arizona State University, PO Box 3701, Tempe, AZ 85287-3701; wkim7@asu.edu.