Developing Collaborative Skills Early in the CS Curriculum in a Laboratory Environment

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ABSTRACT
The research on teaching and learning over the past 50 years suggests that the early use of collaborative learning leads to higher interest, higher retention, and higher academic performance in students. Early use of these techniques can also increase the sense of belonging for students and can lead to the early development of collaborative skills to prepare students for team experiences in subsequent courses and future careers. During the weekly lab sessions of a second semester introduction to programming course students engaged in collaborative learning experiences through team-based problem solving, project planning, pair programming, and other agile software development practices. Course objectives provided specific goals and criteria for assessment relative to these skills. The assessment in the authors' prior work identified several problem areas which led to specific initiatives to address those problems: (a) instructor-chosen teams, (b) early instruction and reflection on team skills, (c) feedback on team performance, and (d) the use of an IDE that incorporates an automated test-driven development tool. This paper describes the implementation and assessment of these efforts. A significant increase in student team skills from the middle of the semester to the end of the semester was observed.

Categories and Subject Descriptors
K.3.2 [Computing Milieux] Computer and Information Science Education – *Accreditation, Computer science education, Curriculum, Information systems education, Self-assessment.*

General Terms
Measurement, Experimentation, Human Factors.

Keywords
Active Learning, Agile Software Development, Assessment, Cognitive-affective Objectives, Collaborative Learning, Laboratory Experiences, Extreme Programming, Feedback, Peer Evaluation, Retention, Sense of Belonging, Team Skills.

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1. INTRODUCTION
Computer Science and related disciplines are seeking to attract and retain quality students and to enhance their academic achievement. This study was inspired by these goals and was implemented in the second semester of our introductory programming sequence. The instructional approach in this study involved the following principle components: (a) a focus on collaborative learning early in the CS curriculum, (b) the use of agile professional practices, (c) the use of cognitive-affective course objectives relating to team skills, and (d) a semester-long lab project. This study investigates the efficacy of these components where specific initiatives were selected based upon assessments in the prior work [19, 20].

1.1 Collaborative learning
Based on a synthesis of 50 years of research on teaching and learning, Chickering identified seven fundamental principles for improvement in undergraduate education: (1) encourage frequent interaction between students and faculty; (2) develop mutual cooperation among students; (3) provide frequent active learning exercises; (4) provide prompt feedback for student reflection; (5) emphasize time on task; (6) set and define high expectations; and (7) respect diverse talents, interests, and learning styles [6]. These seven principles are specifically designed to improve the institution's response to at-risk and unmotivated students [6]. These principles also embody the essence of collaborative learning [4] and have been incorporated into our implementation in this study. Collaborative learning describes learning experiences where students act together to perform specific tasks. Numerous studies have demonstrated the benefits of collaborative learning in the college setting [2, 6, 14, 15, 17, 18, 23, 25]. These benefits over lecture-only approaches include higher academic achievement, higher course success rates and persistence, and higher levels of student interest in learning more about the discipline. Numerous studies also demonstrate collaborative learning benefit nontraditional students, women, underrepresented racial and ethnic groups, commuters, and international students [4]. The benefits of collaborative learning, also contribute to students' sense of belonging and sense of security, and are particularly important for first year students who are at risk of leaving college [27] or leaving the discipline [3, 26]. This research on teaching and learning suggests that the early use of collaborative learning in the CS curriculum may lead to higher interest, higher retention, and higher academic performance.

1.2 The instructional setting of the study

The study was conducted within the second semester of our introductory problem-solving and programming course, CIS 121, during Spring 2005 semester. This course closely corresponds to CS102I, The Object-Oriented Paradigm, in the two-semester model of the imperative-first approach described in Computing Curricula 2001 [1]. CIS 121 is a continuation of our CIS 120 course, the first semester of this sequence, CS1. CIS 121 is a 4 credit hour course with three 50 minute classes and one 75 minute lab per week. These weekly supervised lab sessions were devoted to a semester-long project where the students were assigned to project teams comprised of 5 to 9 students. During each lab session, the students engaged in collaborative learning experiences through team-based problem solving, project planning, and pair programming. The students relied upon a variety of skills and contributions from each team member. The project consisted of the incremental development of a program to manage a computer-recycling system. The teams worked only during the 75-minute lab period with the supervision, observation, and assistance of the instructor and graduate assistants. The instructor, acting as the client, and the graduate assistants, acting as project managers, were considered members of the teams as well.

1.3 Agile practices

In prior work, the authors and other colleagues found that the students benefited from pair-programming; confidence building; a sense of satisfaction and belonging; higher course relevance; and the development of professional skills, such as communication skills, strong work-ethic, commitment, cooperation skills, and adaptability [19, 20]. These team experiences incorporated the following agile practices from Extreme Programming: the planning game, small releases, metaphor, simple design, testing, refactoring, pair programming, collective code ownership, continuous integration, sustainable pace, on-site customer, coding standards, and stand-up meetings [5, 20]. Integrated cognitive-affective objectives [7] were created to promote team-related professional practices in students. These practices were derived from the National Association of Colleges and Employers' (NACE) top-ten list of characteristics most wanted in college graduates [1, 19, 20]. Due to its flexibility, Extreme Programming was a good software development model to use for the lab experience in order to introduce changes into the project as the students learned new concepts during the semester, to give the students ample time for actual coding, to encourage collaborative learning, and promote the objectives of the course. Results from our assessment in the prior work suggested that students not only learned about team skills cognitively but also chose to apply those skills in the lab indicating the internalization of team skills [19].

1.4 Objective-based skill-development

In this study, the students not only participated in collaborative learning, but learned about and reflected upon collaborative skills and put that knowledge into practice. The students' performance in specific skill areas was also evaluated, and the students received specific feedback about their performance. The authors and colleagues have been incorporating integrated cognitive-affective objectives into the CIS curriculum at our university [7, 8, 9, 11, 16, 19, 20, 21]. In this study, cognitive-affective objectives provided a standard to promote and evaluate student growth in the targeted areas. Table 1 lists the cognitive-affective objectives related to specific team skills pursued in this study. These objectives were included on the course syllabus and were promoted during the team experiences in the lab, and through use of exercises, reading assignments, and discussions. Assessment of these objectives was performed using peer evaluations, quizzes, tests, and observations of the instructor and graduate assistants.

Table 1. Integrated cognitive-affective team skills objectives

Communicate with students and faculty about course concepts and practices.
Cooperate with a team in an effort to solve problems and develop software.
Demonstrate a commitment to quality software development with good design and testing practices.
Demonstrate a strong work ethic by attending class and participating fully.
Demonstrate adaptability in software development practices.

2. INITIATIVES OF CURRENT STUDY

The following initiatives were proposed [19] to remedy difficulties found through the assessment of the prior work: (a) instructor-chosen teams, (b) early instruction and reflection on team skills, (c) feedback on team performance, and (d) the use of an IDE that incorporates an automated test-driven development tool.

2.1 Instructor-chosen teams

A problem identified in our prior work was unbalanced teams. The students themselves formed teams, and these teams demonstrated large differences in skill-levels and productivity. The more highly skilled teams became "hot-shots" while less skilled teams occasionally became somewhat discouraged. To remedy this, in the current study, teams were selected by the instructor based upon (a) grades in previous CIS courses, (b) gender, and (c) ethnicity. This information was gathered using a student survey called "Getting to Know You" [22].

2.1.1 Skill-level

In order to give all teams an equal opportunity for a worthwhile and successful experience, each team was assigned members with various skill-levels. Each team was assigned at least one or two students with previous course grades of A or B in prerequisite courses, and at least one or two students with good technical skills. Weaker students were not isolated.

2.1.2 Gender and ethnicity

At our university, like many universities, the percentage of women and minorities majoring in computer-related fields is low. The literature indicates that women benefit from team experiences and from being on teams with other women [12, 13, 24]. For this reason, while not having all women groups, we did not isolate women on otherwise all male teams. Other minority groups as well may be marginalized when isolated in groups [4]. For this reason, while not dividing teams by ethnicity, individual students of different ethnic backgrounds were not isolated on their teams.

Students were placed on teams with at least one other student of the same ethnic background.

2.2 Instruction and reflection on team skills

In our prior work [20], specific areas for cognitive-affective development relating to the team-skill areas were identified: communication, cooperation, work ethic, commitment, and adaptability. However, when we measured student improvement in the prior work, there was no statistically significant difference between the mid-semester and end-of-semester team performance scores. While other data suggested that students benefited from the team experiences, we had no quantitative confirmation that the students' team-skills performance was improving. To further advance this goal, we designed specific initiatives in this study to promote the reinforcement, early acquisition of, and sustained development of team skills.

2.2.1 Reading, discussing, and reflecting on teams

From data collected in our prior study, we found that many of the students did not have previous team experiences. At the beginning of the semester, students were required to read "Coping with Hitchhikers and Couch Potatoes on Teams" [22]. The reading assignment was followed by classroom discussion and a writing assignment about how the issues in the reading assignment pertained to their personal experiences. This provided the students with some knowledge about issues associated with being on a team and some knowledge about how to handle these problems. The writing assignment also provided additional time-on-task for personal reflection about working on a team.

2.2.2 Guide for peer evaluations

Another problem identified by our prior assessments was the students' lack of knowledge about what constitutes good team behavior. To assist students in making informed peer-evaluations of their team members, students were provided a guide with example behaviors for each of the five team skills. The guide was handed out to the students at the time of the peer evaluations. The guide is shown in Table 2 and was created from the qualitative data of the prior work [19].

2.3 Feedback on team performance

Another initiative also designed to foster student growth in the area of team skills was feedback. Specifically, we sought to make feedback prompt and meaningful. About a week after the mid-semester peer evaluation, students were provided individual confidential summaries of their peer evaluations including comments from the instructor and graduate assistants. Every attempt was made to emphasize the best qualities of each student while pointing out areas for improvement. Individual students were then counseled in private by the instructor. During these approximately five-minute meetings, the instructor prompted the student to identify what improvements were needed. The students then were required to write a paragraph describing their best qualities, areas where improvements were needed, and their plans on how to make those improvements.

2.4 IDE to support test-driven development

The students were required to use the Extreme Programming practice of test-driven development. In the prior work, this caused frustration because the IDE used did not support automated test-driven development. In this study, a new IDE, Eclipse, was chosen because of its automated support of test-driven development. Eclipse not only fixed this problem but also gave the students an experience with a professional development tool used in industry. The initial training in the use of Eclipse was provided by an alumni who uses Eclipse as a software engineer.

Table 2. Guide handed out to students to use for examples of team behavior used for peer evaluations [19]

	The Good	The Bad	The Ugly
Communication	"He is good at explaining things to those who are not grasping a particular concept."	"He sometimes talks over weaker members."	"Maybe you should discuss appropriate behavior toward women with him."
Cooperation	"A good quality is her positive attitude and willingness to participate and help where needed."	"Does not contribute to group discussions/effort noticeably or effectively."	"I think he talks out of turn, his comments are inappropriate, and he is disrespectful toward the customer."
Commitment	"He has probably shown the most improvement and most effort on the team. His attitude as well as his ability to program has changed a lot since the first lab. His willingness to improve I think inspires our team"	"The only thing that worries me about her is her lack of enthusiasm. I don't think college is a real priority in her life right now."	"I don't think he really cares about team work."
Work Ethic	"She is willing to learn and take extra steps to dig for material. I feel she is determined to do well."	"He is normally absent and when present never wants to work on the project."	"Sleeps during class, is absent a lot, doesn't really help during lab, just kind of sits back and watches"
Adaptability	"She has an open mind and wants to hear and learn about what others bring to the table. She is also a good listener."	"He is set on his way of thinking."	"Insists on doing things his own ways, not according to the rules and what the customer wants the team to do."

3. ASSESSMENT

The described collaborative learning experiences were assessed using (a) mid-semester and end-of-semester peer evaluations, (b) an objectives/resources student survey, and (c) in-lab observations of the instructor and graduate assistants. The peer evaluations were used to collect both quantitative and qualitative data. A five-point Likert scale was used to quantitatively measure each student's overall contribution to the team, and student comments describing each team member's strengths and weaknesses were used for qualitative data. These instruments were completed for each student by all members of the student's team at mid-semester and at the end of the semester. The objectives/resources student survey used a Likert scale to quantitatively assess the extent to which students perceived the realization of specific course objectives and the impact of learning resources on their success.

3.1 Quantitative Results On Team Skills

The average overall contribution for each student was calculated for the mid-semester and end-of-semester peer evaluations to determine whether there was a significant increase in team skills during the course of the semester. The mean student score (N = 27) for the mid-semester evaluation was 3.98 with a standard deviation of .67, while the end-of-semester evaluation was 4.26 with a standard deviation of .75. This increase was significant, $t(26) = 3.694$, $p = .001$. The standardized effect size index, d, was .71, indicating a strong effect. Because the students' understanding of team skills matured during the semester, we believe that the students' evaluation of team skills may have been more demanding at the end of the semester. We recognize too that some of the observed effect may be the result of over-the-semester maturation not connected with the specific methodologies described in this study.

3.2 Qualitative Results On Team Skills

On each peer evaluation instrument, students were asked to list strengths and weaknesses of team members. The mid-semester peer evaluation information was then summarized and given to each team member as feedback. At the end of the semester, to measure improvements in team skills, the instructor compared the strengths and weaknesses identified by team members on the mid-semester evaluations to the strengths and weaknesses for that same team member listed on the end-of-semester peer evaluations. Table 3 lists sample student comments from the evaluations, showing the weaknesses recorded at mid-semester and the strengths recorded for the same student at end-of-semester. These examples typify the growth in team skills subsequent to the constructive feedback and reflection that followed the mid-semester peer evaluation. Moreover, in the prior work which did not implement this study's initiatives, a similar qualitative instrument revealed several serious team problems that were not resolved. In the current study, comparable problems were resolved quickly before they became "ugly" [19].

3.3 Evaluation of Course Objectives

At the end of the semester students completed an objectives/resources student survey. In the first section of this survey, students were asked to assess the extent to which each of the principle learning objectives of the course were achieved using a Likert scale. Examples of these objectives were "Develop software that involves the use of new classes based upon refining existing classes" and "Write Java programs that involve file input and output." The team-related objective, "Cooperate with a team in an effort to solve problems and develop software" was rated with the highest score.

Table 3. Samples of specific student improvements.

Weaknesses Listed in Mid-semester Evaluation	Strengths Listed in End-of-semester Evaluation
"His way or no way. He's not open minded for other team members' input."	"Committed to the team's goals."
"Sometimes has a tendency to work alone."	"Has become more involved in team work and more adaptable."
"Likes to talk about anything and doesn't always stay on topic."	"Good team player, good attitude, and willing to work."
"Too quiet, needs to communicate with the group more."	"Very inquisitive, voices his ideas very well."
"Doesn't show up and has a bad attitude when she does."	"Has shown up more since the last evaluation." "Helped out a lot."

3.4 Evaluation of Course Resources

On the second half of the objectives/resources survey, the students were asked to rate the extent to which course resources (e.g., the textbook, a supplemental course instruction program, and the programming IDE) had a positive impact on their achievement in the course. Among the list of resources, students rated "the development of team skills" as the most valuable course resource and "the semester-long project in the lab" as the second most valuable resource.

4. CONCLUSION

The evidence in favor of incorporating collaborative experiences into college courses is vast. Benefits include deeper learning, developing skills wanted by industry, having fun, higher retention, higher achievement, higher course success rates, higher interest, and higher sense of belonging. These benefits are enjoyed by all students including underrepresented groups and can be important for first year students who are at risk of leaving the discipline. In this study, the students not only participated in collaborative learning, but reflected upon collaborative skills, and put that knowledge into practice. Moreover, students' performance in specific skill areas was evaluated, and the students received feedback about their performance. This study took place in the context of a lab using agile practices in a semester long programming project where the following initiatives were implemented: (a) instructor-chosen teams, (b) early instruction on team skills, (c) feedback on team-skill performance, and (d) the use of an IDE supporting automated test-driven development. Assessment of this study found (a) a significant increase in student team skills, (b) a quick resolution of serious team problems, and (c) a successful collaborative experience that was valued by the students as contributing to their success. This study confirms that CS students can benefit from the early incorporation of collaborative learning and collaborative skill development.

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