Changing Students' Perceptions: An Analysis of the Supplementary Benefits of Collaborative Software Development

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Abstract

Collaborative work has been in use as an instructional tool to increase student understanding through collaborative learning and to improve student performance in computer science courses. However, little work has been done to understand how the act of collaboration, through pair programming or group work, impacts a student's knowledge of the benefits and difficulties of collaborative work. Experience in collaborative work is essential preparation for professional software development. A study was conducted at North Carolina State University to assess changes in advanced undergraduate students' perceptions of pair programming and collaboration. Student personality types, learning styles, and other characteristics were gathered during two semesters of an undergraduate software engineering course. The study found that, after experiencing pair programming, most students indicated a stronger preference to work with another student, believed that pairing made them more organized, and believed that pairing saved time on homework assignments. Students who disliked their collaborative experiences were predominantly reflective learners, introverts, and strong coders. Those students also cited that a non-participatory partner and difficulties scheduling meeting times outside of the classroom were primary reasons for disliking pair programming. Personality type and learning style had little effect on the changes in perceptions of collaboration.

1. Introduction

University software engineering courses typically introduce students to the social and managerial side of the computer science discipline. In some cases, the projects in these advanced courses involve student teams, creating a shared responsibility and, perhaps most importantly to students, a shared grade on the project. Depending upon the curriculum and course structure of early computer science classes, the concept of collaboration, while essential to professional software development, may be unfamiliar to the advanced undergraduate. However, working together in a team setting is perhaps most important to the shaping of the students as professional software developers. Real-world software development problems are complex and require people to work together to find a solution. To date, relatively little work has been done on the effects of pair programming or collaborative development on student perceptions of collaboration. Student perceptions are important indicators of their reactions to the teamwork required in a professional setting. These perceptions are also important to professors to understand the impact of a collaborative pedagogy on their students.

In this paper, we seek to understand how pair programming and group work affects student perceptions of collaboration. By understanding how and why students react to collaboration, educators can be more aware of how to leverage the positive effects of a collaborative pedagogy in the classroom, and how to proactively reduce the frequency of negative experiences. We examine the results of surveys administered during two semesters of an undergraduate software engineering course at North Carolina State University (NCSU). The surveys are designed to assess students' perceptions of pair programming and of working alone, and how these perceptions change over the course of the semester. We provide statistical analyses of these surveys to examine relationships between student personality types, learning styles, and self evaluations of their traits and their changes of perception. Furthermore, we qualitatively analyze survey responses of students who dislike pair programming to find the sources of this aversion in hopes of creating a positive collaborative experience for all.

The remainder of this paper is organized as follows: related work is discussed in Section 2, the research methods and setting are described in Section 3, findings are presented in Section 4, and we conclude with advice for educators in Section 5.

2. Related work

This section provides a brief introduction to pair programming, the Myers-Briggs personality types, and the Felder-Silverman learning styles. We also summarize some related empirical studies.

2.1. Pair programming

Pair programming is a practice, whereby two programmers work side by side at the same computer, continuously collaborating on the same design, algorithm, code, or test [10]. One of the programmers has the control of the keyboard and the mouse, actively implements the program, and explains the implementation to his or her partner. Studies indicate that students in introductory computer science courses who pair programmed had an equal or higher chance of passing the course with a C or higher, produced better programs, and were more likely to pursue the computer science major than students who solo programmed [11].

2.2. Myers-Briggs

The Myers-Briggs personality types [6] have served as a popular means of characterizing personality traits in both the classroom and the workplace. A considerable amount of work has been published on Myers-Briggs personality types (e.g. [7, 8]). The Myers-Briggs scale has four dimensions.

Introvert-Extravert. Introverts are generally introspective and are energized by spending time alone, whereas extraverts thrive in a group setting.

Sensing-Intuition. Sensors prefer information gathered through experience and are attentive to details, while intuitors prefer abstract concepts and are bored by details, preferring innovative thoughts instead.

Thinking-Feeling. Thinkers rely on objective rationalization to make decisions and are considered to be impartial, whereas feelers are more likely to make subjective decisions based on social considerations rather than strict logic.

Judging-Perceiving. Judgers are typically orderly people who prefer rigid structure and planning but may ignore facts that do not fit their plan or structure, whereas perceivers do little planning and work spontaneously but are more open to facts that do not conform to their views.

Myers-Briggs personality may affect student performance in the engineering classroom. Felder found that, in terms of course grades, introverts outperformed extraverts, intuitors typically outperformed sensors (except in hands-on, “real-world” classes), thinkers outperformed feelers, and judgers often outperformed perceivers [1].

2.3. Learning styles

The Felder-Silverman learning styles have been used to help students understand their own learning needs and to help professors better tailor their courses to different types of students [2]. The purpose of these learning styles is to help characterize the way in which students absorb and retain information. The Felder-Silverman scale has four dimensions:

Active-Reflective. Active learners learn best by trying things out and working with others, while reflective learners learn more by thinking things out on their own.

Sensing-Intuitive. The sensing-intuitive dimension is intended to be the same as in the Myers-Briggs scale.

Visual-Verbal. Visual learners absorb information best through pictures, graphs, and charts, whereas verbal learners prefer written or spoken explanations.

Sequential-Global. Sequential students learn in orderly, incremental steps with one point or fact connecting to the next, whereas global learners have trouble learning fact-by-fact and learn in cognitive leaps after accumulating all the facts.

Some work has been done on the learning styles of computer science students. Thomas, et al. found that reflective learners typically outperform active learners and verbal learners outperform visual learners with respect to exam and course grades [9].

3. Research setting

In this section, we describe the course during which this study was conducted, the methods for gathering data, and the analysis techniques used to elicit our findings.

3.1. Course description

The undergraduate software engineering course at NCSU was project-based and was composed of two, 50-minute lectures and one two-hour closed lab each week. In the lab sessions, the students were partnered with each other to carry out lab exercises or work on homework assignments. The Spring 2005 class had 61 students and had two individual assignments, one paired assignment, and a six-week group (3-4 students) project. The Fall 2005 class had 48 students and consisted of two paired assignments, one individual assignment, and in a six-week group (4-5 students) project. The assignments in both semesters lasted approximately 1-2 weeks.

3.2. Data

The collaboration experiences survey was administered twice during each semester to gauge changes in students’ perceptions of collaboration after having been exposed to pair programming or group work. The collaboration experiences survey was administered at the beginning of each semester. In the Spring 2005 semester, the survey was administered again at the end of the semester, and in the Fall 2005 semester, the subset of the survey was administered after the second paired assignment. The survey results from 78 out of 109 students were pooled from both semesters. Student results were omitted if the students did not complete both surveys or if the data was entered incorrectly. One statistically significant difference existed between the omitted students and those in the study: the omitted students believed they were stronger coders.

The data were gathered via an online peer evaluation tool, PairEval[1]. At the beginning of each semester, the students were assigned to take an online Myers-Briggs Type Indicator (MBTI) test[2] and an online Felder-Silverman learning style (LS) test[3] via the tool. Though these activities were assigned, they were not compulsory and did not affect student grades. The results of the MBTI and LS tests were recorded by the students in the PairEval tool. The students also filled out their initial collaboration experiences survey and a self evaluation survey. The completion of all tests took approximately 15-20 minutes per student. The sample data were analyzed using the SPSS statistical package[4]. The MBTI and LS tests each report their results on an ordinal scale, and non-parametric statistical tests were conducted on all data collected. In both classes, peer evaluations were submitted for partners after each paired assignment and the group project. In the evaluations, students gave their partners an overall rating (scale of 1-9 where 9 is the most positive rating), a compatibility rating (not compatible, OK, compatible), and optionally could leave comments about their partners.

4. Findings

In this section, we present the findings of our study and provide discussion of possible causes and implications of these findings.

4.1. Changes in perceptions of collaboration

The collaboration experiences survey consisted of 13 questions to which students responded on a five-point Likert scale. These questions were motivated by previous studies which attempted to elicit important factors in student compatibility and in the overall appeal of working with another student [4, 5]. We omit one question that was used for instructor feedback only and was not relevant to this study. The Fall 2005 follow-up survey was condensed to five questions due to time constraints and was filled out by students in a text editor then printed and submitted to their respective lab TAs as a part of a weekly lab session. Four of the questions were identical to those on the online collaboration experiences survey. The fifth question is not a part of this study because it was not a part of the online survey. The results are summarized in Table 1. In the table below, the survey question is quoted verbatim, followed by the statistical significance of the Wilcoxon signed ranks test, followed by whether the change in survey responses showed a positive or negative trend. For the four questions which were included in both the Spring and Fall follow-up surveys, the results from both semesters are pooled for use in the statistical analyses (n = 78). For the remaining questions, only the Spring 2005 data is used (n = 49).

[1] http://agile.csc.ncsu.edu/wiki/doku.php?id=tools#paireval
[2] http://www.humanmetrics.com/cgi-win/JTypes2.asp
[3] http://www.engr.ncsu.edu/learningstyles/ilsweb.html
[4] http://www.spss.com

The most significant statistic in Table 1 is the change in the students' preference to work with another student. Students overwhelmingly showed a positive change in their preference to collaborate (Q6) after having experienced pair programming or group-work. Only eight of the 79 student responses were negative changes. Similarly, the students exhibited a preference not to work alone on large projects (Q7). The two remaining statistically significant questions offer some insight as to why students' pairing preferences changed over the semester. The survey responses clearly demonstrated that students believed they became more organized (Q2) and completed assignments faster when working in pairs (Q5).

Table 1: Changes in collaboration experiences

#	**Question**	**Sig,**	**Trend**
Q1	When working with another person, I feel responsible for my partner's success.	0.326	Positive
Q2	I am more organized when I work with others on assignments.	0.001*	Positive
Q3	When solving a difficult problem, I ask other students' advice.	0.085	Positive
Q4	I tend to procrastinate when I work by myself.	0.692	None
Q5	Working with another student saves homework time.	0.024*	Positive
Q6	I prefer to work on assignments with another student. †	< 0.005*	Positive
Q7	I would prefer to work alone on large projects.	0.015*	Negative
Q8	I learn more from working problems out on my own. †	0.084	Negative
Q9	I could avoid a lot of coding errors if I was paired with another student. †	0.254	Positive
Q10	If given a choice, I would always work alone.	0.931	None
Q11	I get new ideas about solving problems from other students. †	0.354	Negative
Q12	When I explain my logic to my partner, I sometimes find errors in my thinking.	0.241	Positive

* denotes statistical significance at $p \leq 0.05$

† denotes questions that appear on the Fall 2005 follow-up survey

While most students showed a positive change toward preferring to collaborate, some students persisted in disliking working with others. Students were classified as disliking collaboration if they responded with either "Strongly Disagree" or "Disagree" to Q6 on both the introductory and follow-up collaboration experiences surveys. Eighteen out of the 78 responders were in this group. We performed qualitative analyses to understand the reasons why these students disliked collaborating. For the Spring 2005 class, end-of-semester retrospectives from the students who disliked pairing were coded and analyzed. In the retrospectives, students answered several short answer questions about their experiences on the group project. In the Fall 2005 class, students were asked to give a short explanation for their answers on the follow-up collaboration survey. In the peer evaluations, only three out of the 18 students who disliked pairing stated that they were compatible with all of their partners on each assignment and project. Eight out of 18 gave at least one partner an overall rating of 6 or less. Apparently, many of these students had partners whom they did not consider ideal, which contributed to a negative pairing experience. Qualitative analysis of the retrospectives and surveys affirms these observations. Twelve of the 18 students mentioned that their partners either did not adequately participate in the assignment or that their partners were not technically savvy, resulting in the unhappy student doing most of the work. Another theme that arose was the difficulties involved in schedule coordination outside of class and lab time. Eight of the students mentioned that finding a common time to meet was difficult, thus making pairing virtually impossible.

Finally, we note that differences exist between the Spring 2005 and Fall 2005 survey responses. Comparing the survey responses from the beginning of each semester yielded no significant differences. However, significant differences existed between all four questions on the Fall 2005 follow-up survey and the Spring 2005 follow-up survey. The Fall semester responses are more negative toward pairing than the Spring semester responses. No statistically significant differences existed in the student personality types, learning styles, and self-evaluations between the semesters. We note that, while not statistically significant, the Fall 2005 semester considered themselves to be stronger coders, to be worse at time management, and had more professional experience.

4.2. Who changed?

We also desired to see if any specific groups of students were particularly influenced by their collaborative experiences. The changes in students' responses to individual questions on the collaboration surveys were correlated with the students' Myers-Briggs type indicators, Felder-Silverman learning styles, and a self-evaluation survey. The self-evaluation survey asked questions such as student's procrastination tendencies, self-confidence in problem solving, interest in coding, and professional experience.

Some significant correlations arose between the collaboration experiences, MBTI and LS values. On the sensing-intuitive scale of the LS, a correlation existed (τ_b=0.178) suggesting that sensors gained a stronger preference to work with a partner (Q6) than intuitors. This may be because sensors prefer experience and tactile information, such as when working actively on a problem with another student. Also, a correlation existed (τ_b=0.229) between intuitors and an increased belief that pairing can help find logic errors (Q12). However, these correlations did not arise on the sensing-intuitor scale of the MBTI, which may be due to differences in the testing instruments used. On the MBTI scale, a correlation existed (τ_b=0.268) between extraverts and an increased likelihood to ask other students for advice (Q3).

Examining the changes in collaboration experiences with student self-evaluations yielded some interesting findings. Students with a higher self-reported work ethic correlated (τ_b=0.264) with an increase in the belief that pairing saves time (Q5). Yet, one might expect that the students with the worst work ethic would benefit the most from having a partner on an assignment. On the other hand, perhaps the students with the greatest work ethic are so because they are not as "naturally" gifted and must work harder to earn their grades and thus benefit from having an additional mind working on the problem. Also, students with a high work ethic are already motivated to manage their time better, and collaborative work encourages this. Conversely, students with a lower work ethic showed an increase in the belief that pairing helped discover logic errors (τ_b=0.382). Perhaps students with a lower work ethic are searching for "quick and easy" solutions that are fault prone. Students who believed that they were quick at solving coding problems correlated with an increase in the belief that pairing helped to avoid logic errors (τ_b=0.287). Thus, even the technically savvy students in the class may find pairing with another student beneficial to uncover errors in their design approach. Finally, a correlation exists between students with higher time management ability and an increase in the preference to work alone on large projects (τ_b=0.264). This last point may indicate an important element of predicting a student's reaction to their paired and group experiences.

Overall, the relationships among the collaboration experiences and student traits are difficult to characterize. Perhaps the most important finding is that collaboration does not appear to benefit any one particular group of students. Instead, elements of pairing and collaborative work seem to appeal to many different types of students.

We attempted to characterize those students who persisted in disliking collaboration and pair programming. Statistical comparison of the group who disliked pairing with the larger sample yielded a few interesting observations. The group who disliked collaborating was significantly more introverted than the general group on the MBTI scale, and was also much stronger toward the thinking end of the thinker-feeler scale. On the LS scale, the group who disliked pairing was significantly stronger toward the reflective end of the active-reflective learner scale. On the self-evaluations, the students in the group who disliked collaborating considered themselves to be significantly stronger coders than the other group. They also were not more organized when working with other students (Q2), did not ask other students for advice (Q3), did not believe that pairing saved time (Q5), preferred to work alone on large projects (Q7), believed that they learn more alone (Q8), and did not believe that pair programming helped avoid coding (Q9) or logic errors (Q12). Two themes emerge. First, the students were almost exclusively reflective learners, and did not gain cognitive benefits by working with other students. Second, the students were confident in their programming competence, and did not require assistance from others.

Those students who did not want to work on assignments with another student were self-assured coders, mostly introverted, and almost exclusively reflective learners. Yet, other students that fit this profile were among the group who *did* prefer to collaborate. While introverts and reflective learners may be naturally predisposed to solo learning, it appears that incompatibility with an assignment partner is the catalyst for determining whether a student will prefer to collaborate or not.

5. Lessons learned

For educators, these findings provide several points for consideration regarding a collaborative pedagogy. It is important that the students were likely to embrace a collaborative method of instruction rather than resist what they were being taught. Students who are positive and appreciative of the material they are being taught are more likely to retain that knowledge and carry the experience into the future. Furthermore, an increase in the organization of the students' approaches to tasks when they collaborate will be beneficial when collaborating on complex tasks in other classes or in a professional career. The students' beliefs that pairing can help them save time on assignments may make them more willing to collaborate with others on projects in professional development, where some form of cooperation is almost always necessary.

One challenge for researchers and educators is to foresee a potential incompatibility between partners and correct it in some way or to proactively avoid incompatible pairs. Research into pair compatibility [4, 5] examined gender, personality types, and other variables, but as yet no formula has been found for ensuring partner compatibility. Another difficult challenge lies in the logistics of student pairing and group work outside the classroom. Many students lead busy lives outside of the classroom, and it can be difficult for them to find a common time and location to meet amidst other class assignments, commuting, and extracurricular activities. This problem has no immediate solution, though some experiments with distributed pair programming have shown some success [3]. Finally, we remind the reader that collaborative assignments are only one portion of the class. There is ample time, in the lecture room and in exam preparation, where individual, reflective learning is required. Anecdotally, we have observed that many of the students who dislike collaboration still enjoy the course.

The key for success when using a collaborative instructional approach, as with any teaching style, is to strike a balance that appeals to all personality types and learning styles. We hope that this study helps educators to better understand the effects that collaborative work can have on their students beyond pair learning and changes in student performance. There are some students who apparently do not see the value of pair programming or collaboration. In the future, we hope to concretely identify the causes of this and, if possible, create an environment where all students can benefit from the supplementary effects of pair programming and collaboration.

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