EFFECTS OF FORMAL LEARNING GROUPS AND OTHER INSTRUCTIONAL METHODS ON RECRUITMENT AND RETENTION OF WOMEN IN UNDERGRADUATE COMPUTER SCIENCE AT CSM

by

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ABSTRACT

According to national surveys, the presence of women in Computer Science (CS) related careers and degree programs is low and continues to decline. Given the importance of gender diversity, especially in a technical field such as CS, it is essential to motivate more women to pursue studies in the field. Introductory level CS courses offer the opportunity to introduce female students to CS, as well as have the potential to shape female students' perception of the field. Therefore, it is critical to make instruction in introductory level CS courses appealing to female students. Studies have shown that recruitment and retention of women in CS can be successful through the use of various instructional methods such as collaborative learning. This thesis explored formal learning groups and other instructional methods used in an introductory CS course (CSCI 101) at the Colorado School of Mines (CSM) and their potential to aid in recruitment and retention of women in CS studies. A more in-depth investigation was conducted regarding students' perceptions of formal learning groups. The participants of the study were students who were enrolled in CSCI 101 during the Spring 2011 semester. Data were collected via surveys, interviews and focus groups, and were analyzed both quantitatively and qualitatively. The results of the study suggest that retention was primarily successful, but that the course and its instructional methods were neither successful nor unsuccessful in recruiting female students. That is, after taking the course, nearly all students who entered the course as CS majors retained their interest in continuing in the major, and of the other students there were not many who gained or lost interest in CS studies. Although there was no clear evidence that any instructional elements of CSCI 101 had an impact on students' intent to study CS, it was found that female students in particular enjoyed learning groups. This suggests that learning groups may have the potential to promote recruitment and retention of women in CS, but that additional research is necessary.

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CHAPTER 1 INTRODUCTION

As percentages of women in computing jobs and university programs decline, recruiting and retaining women in the field of Computer Science (CS) becomes an increasingly important issue. Undergraduate CS programs, and more specifically, introductory level CS courses, offer an opportunity to introduce women to CS studies. Furthermore, learning experiences in introductory CS courses can be pivotal in shaping female students' perceptions of CS. These factors indicate the importance of making instruction in introductory CS courses appealing to women. This thesis explores instructional methods within the Introduction to Computer Science course at Colorado School of Mines (CSM) that have the potential to attract women into the CS major (recruitment) or to encourage women currently pursuing CS studies to continue on that path (retention).

1.1 Current Status of Women in CS

Representation of women in computing-related careers and degree programs is low at a national level. According to the U.S. Department of Labor's 2010 Current Population Survey, only 24% of persons employed in CS-related fields (Computer Hardware Engineers, Computer Programmers, Computer Scientists and Systems Analysts, Computer Software Engineers, Database Administrators, Network Systems and Data Communication Analysts, and Network and Computer System Administrators) are women (Bureau of Labor Statistics 2010). The percentage of women in the U.S. completing bachelor's degrees in computer and information sciences is also much lower than men. The most recent data available from the U.S. Department of Education's National Center for Education Statistics shows that females obtained only 17.8% of those degrees in 2009 (NCES 2010). Although this *percentage* increased slightly from 2008 (from 17.6%), the *number* of women obtaining these degrees declined. Moreover, during the six year period prior to 2008, the percentage of women obtaining these degrees declined each year; in 2002 the percentage was 27.6%, which fell to 22.2% in 2005, and farther to 17.6% in 2008. CS degrees specifically, which are a subset of computer and information sciences degrees, are even less commonly obtained by females. According to the most recent Taulbee Survey conducted by the Computing Research Association, females obtained 13.8% of CS degrees in 2010 (Zweben 2011).

The issue of low participation in the CS major is of particular concern at CSM, an Engineering university with approximately 4,000 undergraduate students. During the time of this thesis research, approximately 13% of the undergraduate students enrolled in the CS program at CSM are female. Moreover, this percentage is lower than the percentage of female students enrolled at CSM, which is approximately 25%.

1.2 Benefits of Recruiting and Retaining Women in CS

While percentages of women in CS-related careers and degree programs remain low, there is great need for women in the field. Motivations behind researching ways to attract and retain women in CS stem partly from the benefits offered by having a higher representation of women in computing-related jobs.

Perhaps one of the most compelling reasons to promote higher numbers of women in computing careers is the advantage realized by companies, educational institutions, and consumers when diversity is present in the workplace. Having women in the workplace and academic environments promotes diversity. Diversity, particularly in a technical field such as CS, brings varied talents, contributions and perspectives, and increases creativity and innovation (Hill, Corbett and St. Rose 2010). These all contribute to improved technology development.

To increase the number of women in CS-related careers, more women must become educated in the field and obtain CS degrees. Students are drawn to CS based on positive early experiences (Tillberg and Cohoon 2005); therefore introductory level CS courses offer the opportunity to recruit more women into the field. Furthermore, since retention of women in computing can be impacted by women's experiences in an introductory level CS course (NCWIT 2008), early courses represent an environment in which efforts to retain women are critical. This thesis work aims at identifying instructional practices that could be applied within an introductory CS course to help motivate women to pursue or continue studies in CS.

1.3 Computer Science 101 at CSM

The research for this thesis explores instructional aspects of the Introduction to Computer Science (CSCI 101) course at CSM, and their effects on recruiting and retaining women in CS. CSCI 101 was first introduced at CSM in Fall 2010. Students who register for the course include CS majors as well as non-majors and students without a declared major. Currently, the course is offered every Fall and Spring semester, an estimated 200-400 students enroll in the course each academic year, and classes have 40 to 60 students each. Approximately 25% of the students enrolled in the course during the Fall 2010 semester were female. In the Spring 2011 semester, approximately 20% of the students enrolled were female.

CSCI 101 is designed to provide an introduction to the field of CS, especially for students who are new to the field. The course incorporates instruction on a broad variety of CS concepts, as well as computer programming in Python (Python 2011). Enrollment in the course does not require any prior experience in computer programming. CSCI 101 incorporates formal learning groups (Johnson, Johnson and Smith 1991) as a primary instructional approach. Other instructional methods implemented in the course include lecturing, use of a widely accepted textbook (Brookshear 2009), and in-class interactive computer games for introducing or reinforcing CS concepts.

Formal learning group work in the course involves both problem-solving activities and sessions in which students teach one another concepts they have learned through individual out-of-class work (learning group assignments). Groups are comprised of roughly five students each. During each class period, students are presented with a learning group assignment and are given time to divide up problems among group members. Each group member is then responsible for investigating specific topics and completing related problems. Groups are encouraged to duplicate coverage on completion of problems between two or more students. An instructor-monitored session in which group members teach one another and discuss their respective findings occurs during the beginning of the following class. As a motivation for students to be invested in teaching their peers, a portion of each student's course grade is dependent on their group members' performance on individually completed quizzes, which are administered at the end of each multi-week time period during which a given set of groups worked together. Groups change approximately three to four times during the course, and group changes occur at logical points in the curriculum (e.g., when coverage of a topic or textbook chapter is complete). Currently, with the exception of the first formation which is completely random, group formations are determined using a randomized algorithm that, based on students' previous grades (including programming assignments and previous learning group quiz scores), creates groups with similar average or median performance. Group formations include differing combinations of females and males, and CS majors and non-majors. It should be noted that during the first two semesters of CSCI 101, including the semester in which data for this study were collected, there were upperclass CS majors taking the course due to a change in the CS program bulletin which allowed them to take CSCI 101 (15% of the students enrolled were upperclass CS majors). The presence of these students in the groups created a different dynamic within the learning groups than is expected in subsequent semesters.

1.4 Research Questions

This thesis aims to evaluate effects of formal learning groups and other instructional methods in an introductory level Computer Science course (Introduction to Computer Science) at Colorado School of Mines. The research questions are as follows:

1. Which instructional methods, including formal learning groups and traditional instructional techniques, do students rank as most effective in promoting their interest in continuing Computer Science studies?
2. What impact do learning groups have on female students in terms of their reported perception of, excitement about, and intent to major in, Computer Science?
3. What impact do specific learning group formations have on female students' reported learning experiences in formal learning groups within an introductory Computer Science course?

CHAPTER 2 LITERATURE REVIEW

The following review of related work discusses previous research conducted on recruiting and retaining women in CS degree programs. It then covers background and research on collaborative learning through formal learning groups, which is the instructional method that is being investigated in depth in this thesis. Finally, this literature review discusses background on research methods that have been selected for this study.

2.1 Recruiting and Retaining Women in CS

Previous studies have shown that recruitment and retention efforts can be successful when done effectively (NCWIT 2011, NCWIT, Cohoon and Barker 2009, NCWIT, Cohoon and Barker 2010). Successful instructional methods for recruiting women into and retaining women in CS programs include techniques that can be used outside of CS instruction as well as techniques that may be incorporated into instruction in introductory level CS courses. Furthermore, many techniques that achieve higher recruitment and retention of female students also carry the added benefits of achieving higher recruitment and retention of all students and/or increasing student performance in general. This thesis work aims to identify techniques that are successful at increasing female participation in CS, so previous research on recruiting and retention methods provides a framework in which to relate the results.

Some methods outside of CS instruction that have been found to be effective in recruiting women into CS include organizing outreach activities targeted at pre-university students (Blum 2001) and encouraging students to attend celebrations of women in computing (NCWIT, Cohoon and Barker 2008). Other methods that have been found to be effective in retaining women who are currently CS majors include mentoring (NCWIT 2011), promoting social activity through a community-oriented CS department environment (Biggers, Brauer and Yilmaz 2008), and avoiding stereotype threats (chances for students to be concerned with reinforcing negative stereotypes about their group) (NCWIT, Cohoon and Barker 2009).

Techniques for optimizing recruitment and retention through instruction in CS courses are more relevant for consideration in this thesis since they may relate either directly or indirectly to instructional methods currently used in Introduction to Computer Science (CSCI 101) at CSM. Details of some of these techniques and their successes at other universities are discussed here.

Some of the most common recommendations based on research findings for recruiting and retaining women in CS involve offering: (a) introductory CS courses with inclusive pedagogies that help boost women's confidence; (b) engaging activities such as media computation; and (c) collaborative learning constructs such as pair programming, peer-led team learning, or in-class cooperative learning (NCWIT 2011).

2.1.1 Inclusive Pedagogies

Studies over the past two decades have shown that there are numerous factors contributing to the fact that women have a lower participation rate in CS than men, including women's perceptions that CS is intimidating, feelings of discouragement, and underestimation of their own abilities in science and mathematics (Cottrell 1992, Fisher and Margolis 2002, Hill, Corbett and St. Rose 2010). There exist stereotypes that computer scientists are "geeks" or "nerds," and CS is often perceived as irrelevant to students (i.e., not perceived as applicable to them); these factors can deter women from the field (Beyer, et al. 2003, Fisher and Margolis 2002, Hill, Corbett and St. Rose 2010). Given the prevalence of these factors, recruiting and retaining more women in CS requires instruction that is inclusive to all students, particularly female students.

Research has been conducted to identify instructional methods that are successful at addressing these factors and getting more female students committed to CS studies. To address concerns that women may view CS as intimidating, or that they may become discouraged by perceived inabilities or by concerns that other students have more programming experience than they do, female students should be encouraged to realize that they can succeed in CS (Tillberg and Cohoon 2005). Furthermore, according to results of a study conducted by Cohoon & Tychonovich (2011) with an introductory CS course at the University of Virginia, early experiences with computer programming should be "hospitable" and should involve smaller, more frequent assignments.

Recommendations for addressing the issue that CS may be perceived as irrelevant include teaching about various applications of CS and presenting CS in meaningful real-world contexts that are relevant to students' experiences (Biggers, Brauer and Yilmaz 2008). Examples of diverse applications of CS include the use of multimedia (e.g., manipulating images and sound to create art) as well as database and network programming (Rich, Perry and Guzdial 2004). Another technique that has been shown to be effective in increasing female students' interest in CS is to use a survey for inquiring about students' specific interests, and later design assignments that relate to those interests (Cohoon and Tychonievich 2011).

2.1.2 Engaging Activities for Improved Interest in CS

Another factor that can contribute to lower participation of women in CS is disinterest (due to viewing CS as boring or lacking an outlet for creativity) (Fisher and Margolis 2002, Hill, Corbett and St. Rose 2010). To overcome this issue, a number of instructional techniques have been proposed, such as, promoting creativity (Rich, Perry and Guzdial 2004), broadening the scope of instruction (Alvarado and Dodds 2010), and using game design to teach programming (Sweedyk 2011). Some of these techniques have been studied and have been identified as beneficial in recruitment and retention of women in CS.

One approach used to overcome the notion that CS is boring, is to encourage creative freedom (Rich, Perry and Guzdial 2004). At the University of Georgia, for example, the CS department offers an introductory CS course that focuses on media computation which teaches programming through media creation and/or manipulation. This approach was positively received by female students in that "the course material and assignments successfully engaged females and interested them in programming" (Rich, Perry and Guzdial 2004, 193).

Another approach is to broaden the scope of introductory CS instruction beyond programming alone, which has shown to be effective in schools such as Harvey Mudd

College (Alvarado and Dodds 2010). This entails covering topics such as theory of computation and computer organization, or incorporating non-programming oriented instructional methods of introducing computing concepts.

Finally, engaging activities associated with fun, such as game design, have been used to promote student interest in CS. Game design has been used as a tool for engaging women in introductory programming courses as well as upper level courses (Barnes, et al. 2007). Harvey Mudd College has introduced game design in its CS instruction and according to the results of a study conducted by Sweedyk (2011), design of serious games or games that serve a purpose other than entertainment alone, was effective with female students. Sweedyk noted that serious games avoided detrimental effects on female students that had been present with other types of games that "ascribe undue authority to gamers" (Sweedyk 2011, 176). When game design is used in CS courses, it is important to consider the types of games used, so as to encourage, rather than deter female students; there are many types of games (e.g., violent games, puzzle games, cooperative games, and competitive games) and women may have an aversion to some of these types (Walker 2003). In addition to game design, other examples of engaging instructional techniques for teaching programming include the use of visual programming languages such as Alice (Carnegie Mellon University 2011) or Scratch (MIT Media Lab 2011), and programming robots (Xu, Blank and Kumar 2008).

One concern that has been raised about using fun instructional methods such as game design, hands-on activities, or programming robots, to introduce CS concepts is that they may be a type of "bait and switch" mechanism; that is, they may make a transition to more complex CS concepts and programming overwhelming and/or disappointing (Kay 2011). While this concern does not indicate that engaging instructional methods should be avoided, it highlights the need to consider possible impacts when using them.

2.1.3 Collaborative Learning as a Recruiting and Retention Tool

One factor that has been identified as a cause for low numbers of women in CS is disinterest in the field due to its perceived lack of opportunities for social interaction

(Cottrell 1992, Fisher and Margolis 2002, Hill, Corbett and St. Rose 2010). The reputation that CS is an asocial field may be a cause for women not pursuing CS degrees initially, as well as a reason for leaving the major. For example, in a study at Georgia Institute of Technology that investigated reasons for students leaving the CS major, students expressed an "overwhelming perception that CS is an asocial, coding-only field with little connection to the outside world" (Biggers, Brauer and Yilmaz 2008, 405).

Collaborative learning, in its many forms, is an approach that can be used in CS instruction to transform these perceptions. In fact, the National Center for Women & Information Technology (NCWIT) identifies integration of collaborative learning in early curriculum as one of the key pedagogical practices for retaining undergraduate students in computing (NCWIT, Cohoon and Barker 2009).

Among collaborative learning constructs that have been shown to have success at retaining women in university-level CS studies is *pair programming*. Using pair programming in CS instruction entails pairing two students together to collaboratively complete programming assignments. Students sit together at one computer and one partner is actively coding (in control of the keyboard/mouse) and the other partner is continuously reviewing the code and strategizing. The partners communicate throughout and take turns in the respective roles. Studies with introductory CS courses at North Carolina State University and University of California-Santa Cruz showed that significantly more female students who participated in pair programming completed and passed the course than those who did only individual programming (McDowell, et al. 2006, Nagappan, et al. 2003). In addition, the study at University of California-Santa Cruz tracked students' majors after their first year and found that more females in the pair programming group pursued CS-related majors (46% of the paired group compared to 11% of the non-paired group).

Peer-led team learning is another collaborative learning strategy that is being used to promote retention of women in CS. Peer-led team learning is a collaborative learning technique in which students in a course are given the opportunity to participate in groups (up to eight students each) that get together regularly (weekly, for example) to work on assigned problem-solving activities under the guidance of an undergraduate "peer leader" who is trained by and follows direction from the course instructor (NCWIT, Cohoon and Barker 2010). While there are differences between peer-led team learning and formal learning groups, such as the presence of one designated / trained team leader, and the fact that the sessions are optional rather than required for coursework, successful aspects of peer-led team learning may also benefit formal learning groups. The University of Wisconsin - Madison, along with seven other universities of differing sizes and status (private vs. public), used peer-led team learning in CS courses over a period of about five years and evaluated its efficacy in retaining students in their CS programs (Horwitz and Rodger 2009). Their evaluation incorporated student surveys and interviews as well as institutional data. Results of the evaluation were promising in that students had positive responses to the peer-led team learning experience, there was a significant improvement in retention of students in the course (i.e., completing the course; not necessarily retention in the CS major), and female students' grades in the course were significantly higher for students involved in peer-led team learning. A later study conducted at Kean University identified some deficits of peer-led team learning and sought out best practices for their use (Stewart-Gardiner 2010). It was identified that peer leaders were important and that groups in which a student rose to the leadership role were most effective. The evaluation also determined that assigned problems "must be constructed with enough leading questions to help students find the path to completion, without giving it all away" (Stewart-Gardiner 2010, 170). Such practices may potentially emerge as successful components of formal learning groups as well.

In-class collaborative learning is yet another approach that may be used to improve female participation in CS studies. Collaborative learning in the college classroom may take the form of single group problem-solving sessions or discussions. It may also take the form of formal learning groups in which students remain with the same group members over a period of multiple weeks (Johnson, Johnson and Smith 1991). Group assignments may be either graded or un-graded; to promote retention of female students in CS studies, it is recommended that students be given opportunities to collaborate on both graded and un-graded assignments (NCWIT 2011). The results of a study conducted at Radford University suggest that the use of formalized collaborative learning in the classroom can significantly improve completion and pass rates for female students in an introductory CS course (Chase and Okie 2000). Their course used cooperative learning groups (Johnson, Johnson and Smith 1991) simultaneously with peer instruction which is a construct that appears to be similar to peer-led team learning. The authors indicated that with the combination of cooperative learning groups and peer instruction, the "WDF rate," or percentage of students withdrawing from the course or receiving a "D" or "F" in the course, was significantly lower for female students during the two semesters of implementation. The WDF rate for females was 18% in the first semester of collaborative learning and 12% in the second semester of collaborative learning, whereas the WDF rate for females was 53% prior to implementing the collaborative learning strategies.

According to Barker et al., incorporating collaborative environments into CS curricula "lead to the development of peer networks, better self-assessments of progress, greater retention in the major, and often, improved learning." (Barker, McDowell and Kalahar 2009, 155). Given that collaborative learning in the CS curriculum has the potential to address some of the well-known factors in low female involvement in CS, there is motivation to further explore collaborative learning as a means to improve recruitment and retention of female students in the CS program at CSM, as intended by this thesis work.

2.2 Cooperative and Collaborative Learning in Undergraduate Instruction

Cooperative and collaborative learning are widely used instructional methods which have been applied in education for centuries (Johnson, Johnson and Smith 1991). The idea of working together to learn dates back to the first century when it was understood that "students could benefit from teaching one another" (Johnson, Johnson and Smith 1991, 1:16). Today's education includes structuring of cooperation and collaboration in the classroom that is based on tested theory and practice. Note that there are subtle differences between the terms "cooperation" and "collaboration." The two terms are often used interchangeably but in the CS field there is typically a distinction which lies in how the group members contribute to learning: "cooperation" involves students dividing up tasks to solve a problem and "collaboration" involves a joint effort to solve the problem together as a group (Dillenbourg, et al. 1996). In this thesis, the terms will be used as distinct words as defined above.

To understand motivations behind the use of cooperative learning in modern education, other types of learning must first be understood. In addition to "cooperative" learning in which students share learning goals, there are two other types of learning: "individualistic" learning in which students have their own goals and do not share goals with others, and "competition"-based learning in which students work against one another to accomplish a goal that can only be reached by one (or only a few) student(s) (Johnson, Johnson and Smith 1991, 1:27). An important point, as stated by the authors, is that "what benefits self" varies between the three learning types. In cooperative learning, benefiting the self benefits others; in individualistic learning, benefiting the self does not affect others; in competitive learning, benefiting the self deprives others. When more students learn as a result of one student achieving a goal, there is a clear victory. Therefore, cooperative learning has advantages over individualistic and competitive learning.

Formal learning groups are a specific type of cooperative learning that have been used in college courses since before the 1990's. The prevalence of their use in CS courses is not currently known to be high, but they are being implemented in other fields. In what follows, formal learning groups as well as group compositions for formal learning groups are discussed.

2.2.1 Formal Learning Groups

This section provides a brief summary of formal learning groups, as outlined in "Active Learning: Cooperation in the College Classroom" (Johnson, Johnson and Smith 1991, 4:1-4:36). Formal learning groups offer the opportunity for students to work cooperatively and collaboratively with other students, under the guidance of an instructor, as an integral part of their learning experience. This type of learning group is typically used to introduce specific content. Group sessions may be problem-solving oriented (collaborative) or investigative, where students break up tasks to individually learn content or solve problems and later teach one another what they have learned (cooperative). Group membership is typically fixed (i.e., the same group of students work together over a period of time), groups are comprised of roughly four students (although this may vary), and groups stay together for a period of several days to several weeks.

A key role of the instructor when using formal learning groups is to guide students; the instructor is "uncovering the material with the students" (Johnson, Johnson and Smith 1991, 4:3) rather than giving material directly to them, as in a traditional lecture format. There are strategies that should be considered in implementing cooperative lessons, which include but are not limited to promoting positive interdependence and requiring individual accountability.

Positive interdependence, or the notion that students rely on one another's successes in order to succeed themselves, is most effective in formal learning groups when all students in the group truly believe that all group members' contributions are necessary and that each group member has unique and specific responsibilities. According to Johnson, Johnson and Smith (1991), getting student groups to accomplish positive interdependence can be achieved in different ways in formal learning groups. One way is giving all students the same reward for the whole group's performance (e.g., assigning a group problem-solving task and awarding all students the same grade for their performance as a group). Another way is giving all students the same goal to achieve (e.g., requiring all students to learn the same material).

Individual accountability, or a requirement that the performance of each individual in the group be assessed, helps to prevent single students from sitting out while other members of the group do the work, and helps to encourage all students to become engaged in the group processes. When employing formal learning groups, techniques for supporting individual accountability include calling on one student to respond for the whole group, observing members' participation in the group, and giving individual assessments where the outcomes, such as grades, impact the whole group.

Other important factors in promoting successful formal learning groups involve the formation of groups themselves. Group composition is discussed next.

2.2.2 Group Formations in Formal Learning Groups

When using formal learning groups in college instruction, teachers may choose to let groups self-form (i.e., have students choose their own group), but assigning groups offers more control in optimizing the group formations for better learning; when groups are formed to maximize heterogeneity, for example, the groups tend to have more diverse contributions, "elaborate thinking," and deeper understanding (Johnson, Johnson and Smith 1991, 4:6).

Research has been conducted on which combinations of students produce the most promising results in group work (Chase and Okie 2000, Johnson, Johnson and Smith 1991, Webb 1989). While the research is not all geared specifically toward formal learning groups and college-level CS education, there may be potential for similarities in outcomes. Learning group compositions may be completely random, or may vary in composition based on factors such as gender, personality, level of experience with related content, or some combination thereof. This thesis investigates whether there are particular group formations that can be identified as being best suited for promoting enrollment of women in CSM's CS program.

Studies show that there are specific ratios of males and females in small groups that foster differing levels of inclusion of all group members (Webb 1989). Results vary between studies; however, it has been identified that there can be negative impacts on female students in groups containing one female and the rest male students. For example, in two studies conducted by Webb, one of which was conducted with students in a computer programming course, it was found that "in majority-male groups, males directed most of their explanations to other males, often ignoring the female." (Webb 1989, 33). While these studies were conducted with seventh and eighth grade students rather than college students, the learning group construct was similar to that of formal learning groups (the students were instructed to help one another learn content).

Personality is another factor in group composition that may be considered. Heterogeneity may be important when considering forming groups based on personality type. In the case of the previously mentioned study at Radford University where cooperative learning groups were used in an introductory CS course and were shown to improve student retention in the course, groups were formed by having students take

Keirsey Temperament Sorter tests (Keirsey 2011) prior to assigning groups, and groups were formed to optimize variety in personality types between group members (Chase and Okie 2000).

Groups may also be arranged by either varying or homogenizing students' ability levels or the level of experience students have with the related content. For example, in a CS course groups can be composed so that all students have roughly the same amount (or varying levels) of experience with computers or with programming. Alternately, groups may be formed so that students have similar or varied ability levels, although ability can be difficult to measure (Webb 1989). Another option is to use students' current performance in the course as a measure for composing groups. Some argue in favor of matching students with similar experience as a way to promote success and retention with collaborative learning (NCWIT 2011). Furthermore, a technique that has been effective in improving recruitment and retention rates in some universities, such as the University of Virginia, is to offer separate courses for students who are experienced and students who are inexperienced (Cohoon and Tychonievich 2011). The success found with this method points to possible success with matching students in learning groups by experience. However, one potential downfall in formal learning groups when organizing groups such that students' experience levels are approximately the same, is that formal learning groups incorporate graded group assignments. Fairness to students would be a concern if low-experience students were grouped together and high-experience students were grouped together.

In summary, there are many different ways in which groups may be formed and there is a great deal to be explored in this area. The context of the cooperation and/or collaboration should be considered.

2.3 Research Methods

Various research approaches are available in the realm of social science, and specifically, educational research. Different study designs and methods for data collection and analysis have been utilized in research and are discussed in this section. While "there is no recipe or formula in making methods decisions" (Patton 2002, 12), background information regarding different methodologies is required to make informed study design decisions. A summary of a variety of methods follows.

2.3.1 Quantitative and Qualitative Research Approaches

Social and educational research may involve quantitative research, qualitative research, or a combination of both (mixed methods research) (Borrego, Douglas and Amelink 2009, Johnson and Christensen 2007, Patton 2002). The different approaches vary in their research objectives, the form of data collected, analysis methods used, and types of results obtained (Johnson and Christensen 2007). The approaches have differing strengths, and different research questions lend themselves to different types of inquiry (Patton 2002).

Quantitative approaches may be used to explain or describe occurrences in terms of numerical or quantifiable measurements, and their data analyses involve identifying statistical relationships (Johnson and Christensen 2007). Quantitative studies often use experimental methods and test hypothetical generalizations (Hoepfl 1997). To obtain data from people, quantitative studies may incorporate the use of closed survey questions such as Likert scale questions (e.g., "How closely do you agree or disagree with … ?"), rank order scale questions (e.g., "Rank the following … according to … ."), and forced-choice questions (e.g., "Which one of the following … ?") (Fink 2009).

Qualitative approaches may be used for exploration and discovery, and their data analyses involve searching for themes and patterns (Johnson and Christensen 2007). Qualitative approaches allow in-depth investigations where quantitative measurements do not adequately describe an issue (Hoepfl 1997, Patton 2002). Furthermore, rather than coming up with a hypothesis and testing that hypothesis to determine whether a theory is correct, in a qualitative approach, a theory may emerge in the process of conducting the research (Corbin and Strauss 2008). Qualitative studies may incorporate the use of open-ended survey questions and/or interviews and focus groups (Corbin and Strauss 2008, Creswell 2007, Patton 2002, Weis and Fine 2000).

Mixed methods entail a combination of both quantitative and qualitative data collection and analysis. In the 1980's, researchers contended that approaches should be exclusively quantitative or qualitative (this position was called the "incompatibility thesis"), but many researchers rejected this thesis, hence the introduction of mixed research (Johnson and Christensen 2007).

2.3.2 Credibility of Research: Validity, Reliability, Rigor and Controlling Bias

For any study to be useful it must be credible (Patton 2002) and researchers should demonstrate the credibility of their studies (Golafshani 2003). In the social sciences, validity and reliability are critical (Carmines and Zeller 1979, Creswell 2007, Golafshani 2003, Patton 2002). In qualitative research, rigor and controlling bias are also important factors influencing a study's credibility (Golafshani 2003, Patton 2002).

Validity and reliability are two important elements of study credibility. Validity, as it is defined in the context of quantitative research, refers to an instrument's or an analysis technique's accuracy, or ability to produce results that measure what they intend to measure (Carmines and Zeller 1979, Fink 2009). Reliability in quantitative research refers to repeatability, or the ability to produce consistent results on repeated uses (Carmines and Zeller 1979, Fink 2009). In quantitative research, instruments should be formally assessed for validity and reliability (Carmines and Zeller 1979, Fink 2009). To ensure reliability and validity in an instrument such as a survey, it is recommended to use those that have already been validated, or have been tested and demonstrated as being reliable and valid (Fink 2009). However, validated instruments may not always be available, in which case qualitative inquiry may be appropriate (Patton 2002). Furthermore, specific strategies may be used to bolster the validity and reliability of quantitative instruments. For example, in closed-question surveys, validity can be improved by providing accurate choices, and reliability can be improved by using clear questions and thorough pilot testing (Fink 2009).

The concepts of and requirements for validity and reliability are viewed differently in qualitative research, and are viewed in various ways among the qualitative research community (Creswell 2007, Golafshani 2003). While the idea of reliability (defined as repeatability) of an instrument may not be relevant in qualitative inquiry (Golafshani 2003), reliability (defined as consistency) in data analysis is important, such as the need for agreement between different coders that responses should be coded a particular way (Creswell 2007). Terms often used to represent the concepts of reliability and validity in qualitative research include 'rigor' and 'trustworthiness' (Golafshani 2003). Strategies that are often used in qualitative research to optimize rigor and trustworthiness include obtaining and confirming data from multiple sources, and having other researchers involved in data review (Creswell 2007).

Rigor in qualitative research refers to employing rigorous methods, data collection, and data analysis, to provide the highest level of quality possible (Creswell 2007, Patton 2002). Rigorous qualitative research typically uses triangulation in various forms (Patton 2002). 'Triangulation' "is the term given when the researcher seeks convergence and corroboration of results from different methods studying the same phenomenon" (Johnson and Christensen 2007, 451). Among the types of triangulation used to improve the trustworthiness and quality of studies are 'methods triangulation' (using multiple methods, such as a combination of quantitative and qualitative), 'data triangulation' (collecting multiple forms of data), and 'analyst triangulation' (using multiple people for analysis and review) (Patton 2002).

Controlling bias is necessary to minimize threats to the validity, or credibility, of any research. There are certain types of bias that should be carefully considered in qualitative research in particular. Potential for biases arises because "the human being is the instrument of data collection" (Patton 2002, 51). Biases associated with data collection are discussed in the contexts of surveys and interviews in section *2.3.3 Data Collection: Surveys, Interviews and Focus Groups*. Additionally, because of the open-ended nature of qualitative research, there are more opportunities for 'researcher bias' (i.e., results being influenced by the researcher's desired outcomes) (Johnson and Christensen 2007). Investigators should take a "stance of neutrality with regard to the phenomena under study" and "enter the research arena with … no predetermined results to support" (Patton 2002, 51). Moreover, researcher bias may be controlled by implementing strategies such as using participants' direct quotations rather than interpreted phrases, triangulating data/methods/analysts, and examining "competing or rival explanations" (Johnson and Christensen 2007, 276).

2.3.3 Data Collection: Surveys, Interviews and Focus Groups

Data may be collected from people via various instruments, such as surveys, interviews and focus groups, which are widely-used data collection methods in educational research (Cohen, et al. 2007, Gorard 2001, Johnson and Christensen 2007).

Surveys are often used to collect quantitative data (through closed questions where the user is forced to respond a particular way) or qualitative, detailed data (through open-ended questions) (Fink 2009). To obtain accurate responses and avoid bias, Fink (2009) suggests careful selection of wording and the use of clear language; survey questions should not use abbreviations and jargon, should be concrete and not excessively lengthy, and should avoid biased and emotionally-charged words and phrases. Pilot testing should be conducted prior to administering surveys to verify that people understand the questions, promoting the collection of valid data (Fink 2009, Johnson and Christensen 2007). Surveys can be lacking when it comes to collecting information regarding perceptions or opinions, so the use of surveys as a part of a larger approach is better (Gorard 2001).

Interviews allow a researcher to delve deeper into participants' perspectives and perceptions through open-ended responses, and add another source of data for triangulation (Patton 2002, Weis and Fine 2000). The format of interviews may vary in the amount of structure, or standardization, in that they can be unstructured/informal (i.e., an open discussion with no specific questions or ordering), completely structured (i.e., having an exact ordering and question wording), or somewhere in-between (i.e., semi-structured), depending on the needs of the study (Patton 2002). For a study in which minimizing variation in the questions asked of the different participants is important, a more standardized/structured approach should be used (Patton 2002). A semi-structured interview, however, which uses a prepared guide or schedule, enables re-ordering of questions and additional probing (Cohen, et al. 2007, Patton 2002). Techniques that are recommended for interview preparation and for conducting interviews are discussed next.

Preparation for interviews involves creating a guide or schedule if applicable, as well as formulating questions and selecting wording that will elicit responses that answer the question as intended. Factors that are important in choosing question wording include allowing for open-ended responses, forming singular questions (i.e., avoiding multiple questions or concepts combined into one) to assure each component is answered, and structuring "why" questions carefully to avoid ambiguity (e.g., ask "what was it about … ?" instead) (Patton 2002).

There are various techniques, as recommended by Patton, that can be used during an interview (Patton 2002, 353-379):

- To minimize biases the interviewer must remain neutral, allowing the interviewee to respond without changing the interviewer's opinion of him/her based on what s/he has shared (i.e., the interviewer should not express anger, shock, etc.), while also maintaining rapport by empathizing with and caring about the interviewee's responses.
- To promote high-quality and relevant responses, the interviewer should show appreciation for the interviewee and let him/her know periodically throughout the interview how his/her responses are helpful.
- When flexibility for additional questions is allowed in an interview's format, probing questions may be asked to increase the depth of understanding of a response by asking follow-up detail questions, requesting elaboration, or requesting clarification. Probing questions should be asked in a conversational manner.
- At the end of the interview, give the interviewee the opportunity to provide additional comments.

As mentioned previously, researcher bias can be mitigated through the use of verbatim accounts from participants. The use of voice recorders to record interviews allows for easy reconstruction of direct quotations from participants (Creswell 2007, Johnson and Christensen 2007, Patton 2002).

Focus groups are a type of group interview that offer the element of interaction among participants (Creswell 2007, Krueger 1998, Patton 2002). As with interviews, focus groups provide an additional data source in a study. Additional advantages include acquiring in-depth data in a short period of time (Johnson and Christensen 2007, Patton 2002), and the benefits of interaction (e.g., it is apparent when views are consistent between or shared by multiple people (Patton 2002)). Many of the strategies for conducting successful interviews are applicable for focus groups, but there are some additional challenges. The focus group moderator should avoid participating in the discussion and shaping the conversation, take notes during the focus group to facilitate distinction between comments (who made which statements), manage the time so that it is not dominated by one or two people, and make all participants feel comfortable participating (Krueger 1998).

2.3.4 Data Analysis

Quantitative and qualitative approaches may be mixed in educational research, in which case a variety of analysis techniques are required (Borrego, Douglas and Amelink 2009, Johnson and Christensen 2007). Generally, quantitative data can be analyzed by identifying statistical relationships, qualitative data can be analyzed by searching for patterns and themes, and mixed research incorporates both types of analysis; moreover, results are reported as a mixture of numerical and narrative descriptions (Johnson and Christensen 2007). Common techniques for analyzing data in social sciences research include calculating descriptive statistics, categorizing and coding open-ended responses, content analysis, and combining different findings.

Descriptive statistics, which provide summaries about a set of data collected, are often used in quantitative research (Johnson and Christensen 2007). Responses to closed survey questions can be represented with descriptive statistics, including measures of central tendency (e.g., mean or median) and frequency of occurrence (numbers and percentages) (Fink 2009).

Categorizing and coding open-ended responses is a common component of analysis in qualitative research (Cohen, et al. 2007, Creswell 2007, Johnson and Christensen 2007). After open-ended survey responses are collected and interview or focus group responses are transcribed, the data may first be stored and organized using software programs to facilitate the subsequent coding process and to improve accuracy (Creswell 2007, Patton 2002).

The next step is for the researcher to read through and take notes on all the data to determine the coding categories (Corbin and Strauss 2008, Patton 2002). For large, complex coding projects, it can be helpful to have two people or teams of people develop the coding categories (Patton 2002). When developing categories, it is important to consider convergence and divergence of categories; first, a determination should be made about what things are similar to one another (convergence) and those categories can be further broken down into finer categories based on dissimilarities (divergence) (Patton 2002). Starting with more categories is often better because the categories can be combined later but cannot be divided after the fact (Fink 2009). Additionally, the categories and codes should be clear enough so that different people would assign the same code for a given response (i.e., the coding scheme should be reliable) (Fink 2009). Note that multiple codes may be associated with a given response, which is common (Fink 2009, Patton 2002), particularly with interview and focus group data where responses are lengthy.

Once categories have been developed and codes have been assigned to those categories, codes are marked for all responses (Corbin and Strauss 2008, Fink 2009, Patton 2002). To eliminate any single interpreter's perspective (i.e., to improve the trustworthiness of the findings) and verify reliability of the coding scheme, at least two people should assign codes independently, and conflicting results should be reconciled (Fink 2009, Patton 2002). Additional coders should have an understanding of definitions and be trained (Fink 2009, Patton 2002). If only one person is coding, it is recommended that s/he recode at least a sample of the data to check for consistency, and a week is sufficient time to "forget the first set of codes so that they are not just automatically reproduced." (Fink 2009, 94). Coded data may then be content-analyzed.

Content analysis in the context of qualitative research is the process of "[taking] a volume of qualitative material and [attempting] to identify core consistencies and meanings" (Patton 2002, 453), or making inferences about meaning (Fink 2009). The types of meanings sought out through content analysis are patterns (descriptive findings), or themes (categorical forms) (Patton 2002). Analysis in qualitative research is predominantly inductive and entails discovering patterns and themes (Borrego, Douglas and Amelink 2009, Creswell 2007, Patton 2002). It is also common to follow up the inductive content analysis by a confirmation process in which deductive analysis or analysis based on an existing framework occurs (Corbin and Strauss 2008, Patton 2002). Interpretation and the emergence of meaning from data (e.g., coming up with a phrase to describe a group of people's similar responses) are key components of the qualitative analysis process as well (Corbin and Strauss 2008, Creswell 2007, Patton 2002). Due to the open nature of interpretation, analyst triangulation or review by other analysts may prevent bias in interpretation (Patton 2002). Furthermore, the analyst should "[return] to the data over and over again to see if the constructs, categories, explanations, and interpretations make sense, if they really reflect the nature of the phenomena." (Patton 2002, 570). To reduce researcher bias, the analyst should also carefully examine aspects of findings that oppose favored outcomes (Johnson and Christensen 2007). Additionally, while the patterns and themes are an important part of creating meaning out of the data, it is still important to report precisely what people stated; the content analysis is not a substitute for the real experiences communicated by the study participants (Patton 2002).

Combining different findings is required when representing data from different collections and analyses, particularly in mixed methods research. In a mixed methods explanatory design, qualitative data are used to help explain the quantitative results; the explanatory design contrasts an exploratory design in which quantitative data are later used to validate qualitative findings (Borrego, Douglas and Amelink 2009). Additional factors are important when combining methods, and as mentioned in section *2.3.2 Credibility of Research: Validity, Reliability, Rigor and Controlling Bias*, credibility of research is influenced by validity, reliability, and/or rigor of the data analysis techniques employed. When quantitative and qualitative findings are integrated, "sample integration validity," or the "degree to which a mixed researcher makes appropriate generalizations from mixed samples" becomes an issue; as an example, when the number of participants providing quantitative survey data and the number of participants involved in interviews or focus groups are disparate, care should be taken in making generalizations, and it should not be assumed that the two groups share beliefs (Johnson and Christensen 2007, 284). Moreover, there is a great deal of variation in combinations of methods, and as such, the researcher should monitor and report their analysis procedures as carefully and truthfully as possible (Borrego, Douglas and Amelink 2009, Patton 2002).

CHAPTER 3 METHODS

The overall goal of this thesis work is an exploration of the effects that specific instructional elements within an introductory Computer Science (CS) course have on recruiting and retaining women in CS. The investigation includes a detailed examination of effects of formal learning groups and specific group formations within learning groups, as related to female students' interest in and intent to study computer science.

This chapter discusses the research approach, including data collection and analysis methodologies, used for this research effort. The discussion on data collection methods includes participant population and selection, as well as procedures and instruments used for data collection, such as surveys, interviews, and focus groups. The data analysis methods discussion includes the quantitative and qualitative data analysis techniques that were used to answer each of the research questions posed in this thesis.

3.1 Research Approach

This investigation included the collection and analysis of data related to students' learning experiences within an introductory CS course (CSCI 101) at Colorado School of Mines (CSM), which is a course designed to introduce students to the CS field. The course incorporates instruction on a broad range of CS topics and uses various instructional methods, including formal learning groups. This investigation also included the collection of data related to students' perceptions of the CS field in general.

Educational research typically involves quantitative research, qualitative research, or a combination of both (mixed methods research) (Borrego, Douglas and Amelink 2009, Johnson and Christensen 2007, Patton 2002). Different approaches may be used depending on the research objectives. This study incorporated a combination of quantitative and qualitative methods, using an explanatory design in which qualitative data were used to help explain quantitative results. The chosen design permits a determination of how many students had various perceptions or intentions (quantitative study), as well as insights into the reasons behind students' perceptions (qualitative study). Although the study incorporated quantitative methods, no experimental research was implemented; that is, no hypotheses were tested.

Data collection took place over the period of two semesters. The first semester of data collection (Fall 2010) was primarily intended as exploratory for the purpose of study development (i.e., identifying areas that could be investigated further or investigated with a different focus, as well as pilot testing). Data collection during the exploratory phase did not include interviews or focus groups. The second semester of data collection (Spring 2011) was used for analysis for the results of this thesis.

The study included administration of surveys to collect both quantitative and qualitative data, as well as individual interviews and focus groups to collect qualitative data from a smaller subset of the students. Various surveys were developed expressly for the purpose of this research. Interviews and focus groups were also conducted to gain insights into students' experiences. Data were collected from both female and male students for comparison purposes. Details regarding the survey, interview and focus group questions can be found in section *3.2 Data Collection* and survey questions can be located in *Appendix A Survey Questions*. Details on the interview and focus group processes can be found in sections *3.2.3 Interviews* and *3.2.4 Focus Groups*, respectively.

Some survey questions were asked both at the beginning and at the end of the semester in which participating students took CSCI 101 (pre/post survey) to assess students' changes in perceptions of CS and instructional methods such as formal learning groups and Python programming, as well as their intent to pursue CS studies. In order to obtain information regarding which elements of CSCI 101 impacted students either positively or negatively, students were asked at the end of the course via surveys and individual interviews to self-report which components of course instruction they believed had an impact on them and why. An additional investigation was completed regarding students' perceptions of formal learning groups and how they relate to students' performance in the course, level of commitment to pursuing a CS degree, and perceptions about computing. Finally, for the purpose of exploring the effectiveness of specific group formations (combinations of students), students were asked various questions about each of the groups in which they participated during the semester.

Survey data were analyzed quantitatively, for the purpose of summarizing numerical data, or qualitatively, for the purpose of identifying common themes in students' perceptions. Interview and focus group data were analyzed qualitatively to identify details of students' perceptions and capture examples of students' experiences.

A timeline representing the various data collection, survey development, and analysis events, is provided in Figure 3.1.

Fall 2010 Dates	**Fall 2010 Events**	**Spring 2011 Dates**	**Spring 2011 Events**
		Late January 2011	Pre-Survey
Early November 2010	Pre-Survey		
Mid December 2010	*Learning Group Surveys*	*April to May 2011*	*Learning Group Surveys*
Mid December 2010	Post-Survey	Early May 2011	Post-Survey
		Mid May 2011	**Interviews and Focus Groups**
December 2010 / January 2011	***Fall 2010 Data Review, Survey Revisions***	***Summer/Fall 2011***	***Spring 2011 Data Analysis***

Figure 3.1. Study Timeline.

3.2 Data Collection

Each of the three *research questions* addressed in this thesis work, as defined in section *1.4 Research Questions*, were investigated through a combination of various forms of data collection, including surveys, interviews, and focus groups. All data were self-reported by participating students. The participant population included students who were enrolled in CSCI 101 in Fall 2010 (pilot testing only) and students who were enrolled in CSCI 101 in Spring 2011; there were 111 students (27 females and 84 males) enrolled in Fall 2010 and 102 students (20 females and 82 males) enrolled in Spring 2011. The procedures for data collection and handling for this research were reviewed and approved by the CSM Internal Review Board (IRB). The research received an exemption for human subjects research. The exemption letter can be found in *Appendix C IRB Exemption Letter*.

Each *research question* was explored through the use of survey items that were specifically designed to address the given question, followed by additional individual and/or group interviewing. Tables 3.1 through 3.4 outline the questions that students were asked, as well as the instrument(s) in which those questions appeared, to address each specific *research question*. The questions presented in Tables 3.1 through 3.4 are the ones that were used for the Spring 2011 data collection and analysis; those questions had been modified or developed based on the results from pilot testing in Fall 2010.

To examine research questions one and two, "Which instructional methods, including formal learning groups and traditional instructional techniques, do students rank as most effective in promoting their interest in continuing Computer Science studies?" and "What impact do learning groups have on female students in terms of their reported perception of, excitement about, and intent to major in, Computer Science?" students' intent to study CS and their perceptions of computing in general were obtained. Table 3.1 shows the questions that were asked to obtain such information, as well as the instrument(s) through which the data were collected. Some questions were only asked at the beginning of the semester (noted as "Beginning Survey" in Table 3.1), whereas other questions were asked at the beginning and end of the semester for the purpose of comparison (to determine how students' reports changed after taking CSCI 101); those questions are noted as "Pre/Post Survey" questions in Table 3.1.

To examine the first research question, "Which instructional methods, including formal learning groups and traditional instructional techniques, do students rank as most effective in promoting their interest in continuing Computer Science studies?" students were surveyed about their changes in interest in studying CS (see Table 3.1) and about their perceptions of different instructional methods that were used in CSCI 101. Table 3.2 shows each of the questions that were asked, as well as the instrument in which each question was used.

Table 3.1. Questions asked to determine how students report their interest in studying CS and computing in general.

Question for Students	Instrument(s) in which Question Appeared	Research Question Being Addressed
List your declared majors and/or minors. For each, enter the date you declared.	Beginning Survey	Intent to Study CS (For research questions 1 and 2)
Are you considering further studies in CS in any of the categories below? If so, check all categories you are considering. If not, check "None". Major // Minor or ASI (Area of Special Interest) // Taking additional CS courses w/o pursuing CS major/minor/ASI // None	Pre/Post Survey	
Likert*: Computing is fun.	Pre/Post Survey	Perceptions of Computing (For research questions 1 and 2)
Likert*: Computer programming is difficult.	Pre/Post Survey	
Likert*: Computing-related jobs are boring.	Pre/Post Survey	
Likert*: I am interested in a computing-related career.	Pre/Post Survey	
Likert*: I am interested in how computer hardware works.	Pre/Post Survey	
Likert*: I am interested in learning how to design and/or develop computer software.	Pre/Post Survey	
Likert*: Computing is useful in everyday life.	Pre/Post Survey	
Likert*: Learning computing skills will help me during college.	Pre/Post Survey	
Likert*: Developing computing skills will help me in my career.	Pre/Post Survey	

* All Likert-type questions offer "Strongly Disagree," "Disagree," "Agree," and "Strongly Agree" as response options.

Table 3.2. Questions asked to investigate how students compare different instructional methods used in CSCI 101.

Question for Students	Instrument in which Question Appeared	Research Question Being Addressed
Rank the following in CSCI 101 in terms of how much you learned from each of them: Reading the Textbook / Participating in Learning Groups / Observing Lecture / Programming in Python / Playing/Watching Computer Games	End Survey	**<u>Question 1: Instructional Methods</u>** Which instructional methods, including formal learning groups and traditional instructional techniques, do students rank as most effective in promoting their interest in continuing Computer Science studies?
Rank the following in CSCI 101 in terms of how much you enjoyed learning from each of them: Reading the Textbook / Participating in Learning Groups / Observing Lecture / Programming in Python / Playing/Watching Computer Games	End Survey	
What aspects of CSCI 101 did you like / dislike most? Explain.	Interview, Focus Group	
Have you had any changes in your interest in CS or intent to pursue CS studies since taking CS 101, and if so, were any particular elements of the course that had an impact?	Interview	

To examine the second research question, "What impact do learning groups have on female students in terms of their reported perception of, excitement about, and intent to major in, Computer Science?" students were surveyed about their changes in interest in CS (see Table 3.1), and asked additional questions about their experiences in learning groups. Table 3.3 shows each question along with the instrument(s) in which it appeared.

Table 3.3. Questions asked to investigate students' perceptions of learning groups in CSCI 101.

<table>
<tr><th>Question for Students</th><th>Instrument(s) in which Question Appeared</th><th>Research Question Being Addressed</th></tr>
<tr><td>How do you think learning groups compare to traditional learning methods (e.g. lecture and textbook)?</td><td>End Survey</td><td rowspan="5"><u>Question 2: Learning Groups</u>

What impact do learning groups have on female students in terms of their perception of, excitement about, and intent to major in, Computer Science?</td></tr>
<tr><td>What aspects of learning groups did you like / dislike most?</td><td>Interview</td></tr>
<tr><td>Likert: I will have / had fun working in formal learning groups in CSCI 101.
Options: Strongly Disagree /Disagree /Agree /Strongly Agree</td><td>Pre/Post Survey</td></tr>
<tr><td>Did working in learning groups have any impact on your intent to pursue further studies in Computer Science? Explain.</td><td>End Survey, Interview</td></tr>
<tr><td>Please provide any additional comments you have regarding your experience with learning groups in this course.</td><td>End Survey, Interview, Focus Group</td></tr>
</table>

To examine the third research question, "What impact do specific learning group formations have on female students' reported learning experiences in formal learning groups within an introductory Computer Science course?" students were asked to evaluate each group in which they participated, rank their groups based on different criteria, and describe properties of the groups that worked well or did not work well based on different criteria. Table 3.4 shows each question along with the instrument in which it appeared. Questions that pertain to one specific group only, are noted as "Group-Specific Survey" questions in Table 3.4.

Details regarding the data collection methods used in this investigation, including information about how participants were selected and how surveys, interviews, and focus groups were conducted, are provided in the following sections.

Table 3.4. Questions asked to investigate students' experiences in learning groups with different formations.

Question for Students	Instrument(s) in which Question Appeared	Research Question Being Addressed
Likert*: This group promoted creativity.	Group-Specific Survey	**Question 3: Learning Group Formations** What impact do specific learning group formations have on female students' reported learning experiences in formal learning groups within an introductory Computer Science course?
Likert*: I had fun with this group.	Group-Specific Survey	
Likert*: This group was conflict-free.	Group-Specific Survey	
Likert*: This group motivated me.	Group-Specific Survey	
Likert*: This group made me feel confident in my abilities.	Group-Specific Survey	
Likert*: In this group, I felt comfortable contributing.	Group-Specific Survey	
Likert*: I learned a great deal from this group.	Group-Specific Survey	
Likert*: I got excited about computer science with this group.	Group-Specific Survey	
Rank [each of your learning] groups from most effective to least effective.	End Survey	
Consider the most effective group. What was it about this group that made it effective?		
Consider the least effective group. What was it about this group that made it less effective?		
Rank [each of your learning] groups from most inclusive to least inclusive, where inclusive means you felt included in the group and felt comfortable teaching and asking questions of your group members.	End Survey	
Consider the group in which you felt most included in the teaching and learning process. What was it about this group that made you feel included?		
Consider the group in which you felt least included in the teaching and learning process. What was it about this group that made you feel less included?		
What group formations (combinations of students, experience levels, gender, etc.) were most / least effective and why?	Focus Group	
Did you feel more comfortable in groups with no other females, or groups with other females, or does it not make a difference? Explain.	Interview [females only]	

* All Likert-type questions offer "Strongly Disagree," "Disagree," "Agree," and "Strongly Agree" as response options.

3.2.1 Selection of Participants

This thesis work involves assessing effects of instructional methods in an introductory level CS course as they relate to recruiting and retaining women in CS. Furthermore, the research took place at Colorado School of Mines (CSM), an engineering school where the percentage of female students majoring in CS is low. As a result, the population being studied is that of students taking the Introduction to Computer Science course at CSM (CSCI 101). Following are brief explanations of participant recruiting, participant consent, and protection of participants.

When surveys, one-on-one interviews, and focus groups were conducted for the purpose of this project, all students registered in CSCI 101, regardless of their gender or any other factors, were given the opportunity to volunteer to participate. That is, students were encouraged, but not required, to participate. Data were not collected anonymously. *Participants were recruited* via announcements during class, informing them of the option to participate. All students were invited to complete the surveys, whereas a random selection of students were asked to participate in interviews and focus groups. The process for random selection was as follows. All female students were invited to participate in either an interview or a focus group. Of the 20 female students, three were no longer participating in CSCI 101 (e.g., withdrew from the course) and were therefore not included in the pool of students from which participants were randomly selected. First, female students were selected at random for interviews. If a student was chosen, but was unable (unavailable or unwilling) to participate in an interview, another student was selected. This process continued until four interviews were confirmed. All remaining female students were selected to participate in a focus group. A total of eight female students were able to participate in a focus group, and they were divided up evenly into two focus groups based solely on which time slot each student was available. The number of male students selected was chosen to match the number of female participants. Of the 82 male students, two were no longer participating in the course and were therefore not included in the selection pool. Male students were randomly selected until four interviews were confirmed (following the same process as for female students). Male students were then randomly selected one at a time until eight male students were confirmed to participate in a focus group. Those eight male students were divided up evenly into two focus groups based on which time slot each student was available. Ultimately, for each gender, four interviews and two focus groups were conducted. The focus groups were intended to have four students each; due to the absence of two male students, however, both male focus groups had only three students each. The random selection process was conducted using the Python pseudo-random number generator.

Each student was assigned a number, and each selection occurred by having a number randomly selected from a list of numbers (the available selection pool). Once a student was selected, his/her number was removed from the list.

Regarding *participant consent*, students were informed of the respective procedures for completing surveys, or for participating in interviews or focus groups. Participants were given the investigator's contact information in the event that they had questions regarding the research. To minimize undue influence, prior to consenting to participate, students were made aware that their responses would be dissociated from their names and that the instructor of CSCI 101 who was in charge of their grades would not see their responses until after their names had been replaced with unique identifiers, ensuring that their responses would not impact their grades. Participants were further informed that the investigator (a co-instructor for the course) would see their responses, but that their responses would not be shared with their classmates.

Participants were protected in the following ways. All student data were stored on secure (password- and firewall-protected) computers. When participants' names were captured for tracking purposes (for association and/or comparison), each participant's name was mapped to a unique identifier unrelated to the participant's name. All data were stored and analyzed with these unique identifiers. Some surveys were conducted through secure online website applications. Other surveys were completed on paper. Any data on paper were input into a secure computer and the paper documents were destroyed. Interview and focus group responses were recorded digitally, transcribed, and stored on a secure computer with unique identifiers rather than student names. Moreover, interviews and focus groups were held in private rooms to prevent contents from being heard outside of the setting of the interview/focus group.

3.2.2 Surveys

Surveys offer a method of collecting quantitative and qualitative data from study participants through closed and open-ended questions, respectively. Much of the data collection for this investigation occurred through the administration of student surveys. Survey questions were developed specifically for the purpose of this research. While those surveys were not validated, measures were taken to optimize the accuracy and reliability of the surveys. For example, before conducting surveys to collect data for analysis for the study, pilot testing was conducted with students taking CSCI 101 in Fall 2010 to verify that students could understand the questions. Pilot testing is suggested by Fink (2009) and Johnson & Christensen (2007) as a way to obtain more valid survey data. Results from those surveys were used to shape further development of the instruments used to collect data during Spring 2011 (for analysis for this thesis). For example, there were some questions on the surveys for which it was evident that the wording did not communicate the intended meaning properly. Those questions were reworded to address such concerns. Another example was determining whether additional questions were necessary for obtaining the desired data. Based on the results of the Fall 2010 surveys, some questions were added to the final surveys used in Spring 2011.

The Spring 2011 surveys were administered through a secure online website application. During the pilot testing, some of the surveys had been completed on paper, and certain problems occurred such as students placing an X between squares on a closed scale question. The decision to use web-based surveys across the board in Spring 2011 was made to force responses (eliminating the possibility of not answering properly), as well as to offer a convenient method for students to complete all of the surveys on their own time.

The questions included in the surveys were related to students' background information, perceptions of CSCI 101, perceptions of computing in general, and intent to study and/or major in CS, as well as students' perceptions of formal learning groups and other instructional methods used in CSCI 101. Tables 3.1 through 3.4 in section *3.2 Data Collection* display all survey questions that appeared on the surveys in the context of the research question(s) they are intended to answer. Additionally, as shown in the study timeline in Figure 3.1, there were three different rounds of surveys: (1) Pre-Survey; (2) Learning Group Surveys; and (3) Post-Survey. All surveys requested participants' names so that responses could be linked to individual students between surveys.

The *pre-survey* contained questions that were only asked at the beginning of the semester as well as pre/post survey questions that were used for comparison purposes. At the beginning of the semester, students were asked some general background questions, a question about why they were taking CSCI 101, and a question about their declared major(s) and/or minor(s) coming into the course. Self-reported background information included gender, age, and level of academic progress (i.e., how long they attended CSM); the primary purpose for collecting this information was to classify students in different categories (e.g., classify them by gender) for comparison purposes. Students were asked their age to verify that they were not minors (required by IRB). See section *A.1 Beginning Survey Questions* in the Appendix for a complete list of questions asked only at the beginning of the semester. The pre/post survey questions were closed questions, and students were asked identical questions at the beginning and end of the semester so that a difference in their opinions could be measured. Students were asked to report their intentions for continuing studies in CS. They were also asked a number of Likert-type scale questions related to their perceptions of computing, CSCI 101, and formal learning groups. The Likert-type questions "forced" the students to provide a response by offering the following answers: strongly disagree, disagree, strongly agree, and agree (a four-point scale in which the neutral response was not available (Fink 2009) was used). See section *A.2 Pre / Post Survey Questions* in the Appendix for a complete list of pre/post survey questions.

The *learning group surveys* asked students Likert-type scale questions about an individual learning group (a particular set of group members with whom they worked). Students completed a separate survey for each group, and the surveys were issued as close to the termination of each group as possible; however, the first two group surveys were not given until later in the semester (not immediately after the group took place). The survey questions were aimed at evaluating different groups based on how comfortable students felt participating in them, how much students enjoyed them, etc., for the purpose of examining effectiveness of various group formations. See section *A.3 Learning Group Survey Questions* in the Appendix for a complete list of group-specific survey questions.

The *post-survey* contained pre/post survey questions, as well as questions that were only asked at the end of the semester. As mentioned previously, section *A.2 Pre / Post Survey Questions* in the Appendix contains a complete list of pre/post survey questions. Questions asked only at the end of the semester included closed questions that were aimed at determining which instructional methods students reported learning from and enjoying the most, as well as open-ended questions to investigate student's perceptions of learning groups and group formations. Students were also asked to compare their different groups in terms of how much they felt included in and learned from those groups. See section *A.4 End Survey Questions* in the Appendix for a complete list of questions asked only at the end of the semester.

One-on-one interviews and focus groups were held shortly after the post-survey was completed for the purpose of obtaining additional feedback regarding students' changes in perceptions of computing, intent to pursue further CS studies, and experiences with the course and its various instructional methods.

3.2.3 Interviews

Interviews provide the opportunity for a researcher to explore study participants' perceptions in greater depth than surveys alone. For this research, one-on-one interviews were conducted with a randomly selected portion of the students who took CSCI 101 in Spring 2011 to capture illustrations of students' experiences in CSCI 101, and in learning groups. Since this research is focused on female students, an attempt was made to have all female students participate in an interview or focus group. Four female students participated in an interview. To match that number, four male students also participated in an interview. More information regarding the selection process is available in section *3.2.1 Selection of Participants*. All interviews (and focus groups) took place after the students had taken the final exam, but before they received their final grades.

The researcher personally conducted the interviews. A voice recorder was used to ensure exact replication of students' responses. The interviews were later transcribed by a research assistant and reviewed carefully by the researcher to assure that the students' responses were recorded precisely.

The interviews were semi-structured; that is, all students were asked the same set of questions but during the interview, additional questions were permitted when probing was needed (e.g., further investigation of a topic or clarification of what a student had said), and students were given the opportunity at the end of the interview to provide any general comments they wished to add. Prior to the interviews, questions were created to duplicate some of the questions asked in surveys or to further explore students' perceptions. At the recommendation of Patton (2002), questions were worded to be clear and designed to elicit truly open-ended responses.

During the interviews, several measures were taken to minimize bias. To optimize neutrality, the interviewer informed students at the beginning of the interview that their responses would not affect their grade in any way or be shared with anyone prior to their name being dissociated from their identity. Furthermore, during the interviews, deliberate efforts were made to encourage responses of all types and show interest in students' responses regardless of their tone and whether they represented positive or negative views of elements of CSCI 101. Given that the interviewer was a co-instructor of the course, those measures were especially important for these interviews.

Participants were encouraged to openly share their thoughts about learning groups and their experiences in CSCI 101. They were asked which aspects of instruction in CSCI 101 they liked and disliked, and why. They were also asked about their perceptions of learning groups in particular, including which aspects they liked and disliked, and what impact the groups may have had on their interest in studying CS.

3.2.4 Focus Groups

Focus groups are a type of group interview that introduce the dynamic of interaction between participants. For this project, focus groups were conducted with a small portion of the students who took CSCI 101 in Spring 2011, as a way to obtain detailed information beyond what was obtained from interviews. Two focus groups with four female students participating in each one were conducted. Two focus groups were also conducted with male students. Although an attempt was made to have four males in each focus group as well, only three attended each male focus group. Details regarding the selection process for focus group participation are available in section *3.2.1 Selection of Participants*.

Before the organization of the focus groups, a question guide was developed for use in directing the discussion. The focus groups were semi-structured and all focus groups were conducted using the same question guide. Similarly to the interviews, additional questions were permitted when probing was needed and measures were taken to avoid bias. Moreover, the moderator interjected as necessary to make all participants feel comfortable participating, to encourage all students to participate in each question's discussion, and to prevent individual students from dominating the discussion.

As with the interviews, a voice recorder was used. Brief notes were taken during the focus groups to track who said what. The focus groups were later transcribed by the moderator/researcher who was familiar with the students' voices, to optimize the accuracy regarding which student made each statement. The transcriptions were re-reviewed along with the voice recordings to verify that students' responses were transcribed correctly and associated with the correct student.

During the focus groups, students were asked to discuss from which instructional methods in CSCI 101 they learned the most, learned the least, enjoyed the most, and enjoyed the least. Students were also prompted to discuss which of their groups were most and least effective and why (e.g., groups with students of differing experience levels or gender).

After surveys were administered and interviews and focus groups were conducted, data were analyzed both quantitatively and qualitatively to evaluate the effects various aspects of the course had on recruitment and retention of students, especially female students.

3.3 Data Analysis

Data analysis for this research consisted of quantitative analysis, using descriptive statistics to demonstrate findings regarding closed survey questions, as well as qualitative analysis, using categorization/coding to synthesize open-ended survey responses. Furthermore, interview and focus group data were qualitatively analyzed to summarize typical student experiences.

The analysis approach used to answer each of the three research questions posed in this thesis is described in the three sections that follow. Several general analysis strategies that were implemented throughout the analysis process are outlined next.

Those analysis strategies include storing and organizing data electronically, summarizing Likert responses and/or comparing pre-survey and post-survey Likert responses, categorizing and coding open-ended responses, and summarizing interview and focus group responses.

All data were stored and organized electronically prior to data analysis. All survey data were consolidated into a spreadsheet in which all responses were stored. Each student was assigned a random number between 1000 and 1999. All of the student's responses from the surveys administered at the beginning and end of the semester were stored with that random number. Group-specific survey data were stored separately; each group also had a unique identifier (all 3-digit numbers less than 1000), so each response was linked to both the respondent's unique student identifier and the group identifier for the group the student was evaluating. Data were stored such that they could be reviewed for individual students or for groups. Information for all group members (e.g., gender, major/non-major, etc.) was available for each group. Transcribed interview and focus group data were also stored using students' unique identifiers.

Likert responses were summarized and pre/post Likert responses were compared. The Likert-type scale questions in surveys were posed as statements where students were asked to indicate their level of agreement with the statement on a four-point scale from Strongly Disagree to Strongly Agree. For analysis, responses were coded with a 0 for "Strongly Disagree," a 1 for "Disagree," a 2 for "Agree," and a 3 for "Strongly Disagree." To summarize data, the number or percentage of female students, male students, and/or all students combined, who answered a particular way (e.g., "Agree"), could be counted. Furthermore, the number or percentage of students (female, male and/or all), who answered positively (e.g., either "Agree" or "Strongly Agree") or negatively could also be counted. Such counting was possible since each response was linked to the unique identifier of the student who responded, and information such as gender was available for each identifier. To compare a Likert response given at the beginning of the semester to the response for the identical question given at the end of the semester, the number coding described previously (i.e., 0 through 3) was first applied to the pre-survey response and post-survey response for a given student. Changes were then measured by subtracting the response codes. For statements that are considered to be positive statements, such as "Computing is fun," or "This group made me feel confident in my abilities," an improvement would be considered an increase in the response from the beginning to the end of the semester. For positive statements, the calculation used to determine the level of improvement was the post-survey response minus the pre-survey response difference. On the contrary, for statements that are considered to be negative statements, such as "Computing programming is difficult," or "Computing-related jobs are boring," an improvement would be considered a decrease in the response from the beginning to the end of the semester. For negative statements, the calculation used to determine the level of improvement was the pre-survey response minus the post-survey response difference. The change difference ranges from -3 (the highest level of decline: *0/"Strongly Disagree" minus 3/"Strongly Agree"*), to +3 (the highest level of improvement: *3 minus 0*), where a change of 0 indicates no change from the beginning to the end of the semester.

Open-ended survey responses were categorized and coded. After survey responses were stored electronically, each student's response for a given question was available for review. The researcher read through the responses several times, taking notes on types of responses that appeared. Through an iterative process, categories, and typically subcategories, were created and then documented with specific codes. Generally-similar responses were identified and categories were created for those types of responses. When necessary, those categories were broken down further into subcategories based on dissimilarities. Once the specific categories were determined and each category had a code associated with it, the researcher then assigned a code or codes to each student's response. To improve the trustworthiness of the coding a second person, a research assistant, was trained on the coding process and independently assigned codes to each student's response. Discrepancies were discussed and reconciled between the two coders.

Students' responses in interviews and focus groups were summarized. All students' responses to a given question (verbatim accounts from transcriptions) were collected in one location electronically. All of each student's responses (to all questions) were also stored in one location so that all of that particular student's responses could be considered as a unit. The researcher examined the responses for each question and took notes on the types of responses that were given, developing general categories. In the case of questions that were identical or similar to a survey question that had been given, codes that had been developed for that survey response were considered. Details of students' experiences and perceptions were summarized based on their responses to the various questions.

Specific analysis approaches for each research question are explained in the three upcoming sections.

3.3.1 Analysis of Instructional Method Impacts

To determine which instructional methods students found to be most effective in promoting their interest in continuing CS studies, an analysis of how they rank the different instructional methods was conducted. Figure 3.2 summarizes the specific analysis methodologies that were used for each type of data collection. Additionally, details of analysis techniques are provided below.

After taking CSCI 101, students were asked to rank five different components, or learning modalities, of the course based on how much they learned from them, as well as how much they enjoyed learning from them. The five components were "reading textbook," "participating in learning groups," "observing lecture," "programming in Python," and "playing/watching course-specific video games." Data analysis involved tallying the number of students who ranked each of the learning modalities as the one from which they *learned the most* (ranked number 1), and then tallying the number of students who ranked each of the learning modalities as the one they *enjoyed* learning from *the most*. Tallies were completed and percentages were calculated for female students, for male students, and for all students combined.

Students' changes in intent to continue studying CS were also measured. While no direct correlation can be made between students' rankings of the various learning modalities and their intent to study CS, those data were also compiled so that connections could be made between individual students' learning preferences and their changes in interest in CS studies. Students were asked to what extent they intended to pursue CS studies, specifically whether they were considering a major, a minor or Area of Special

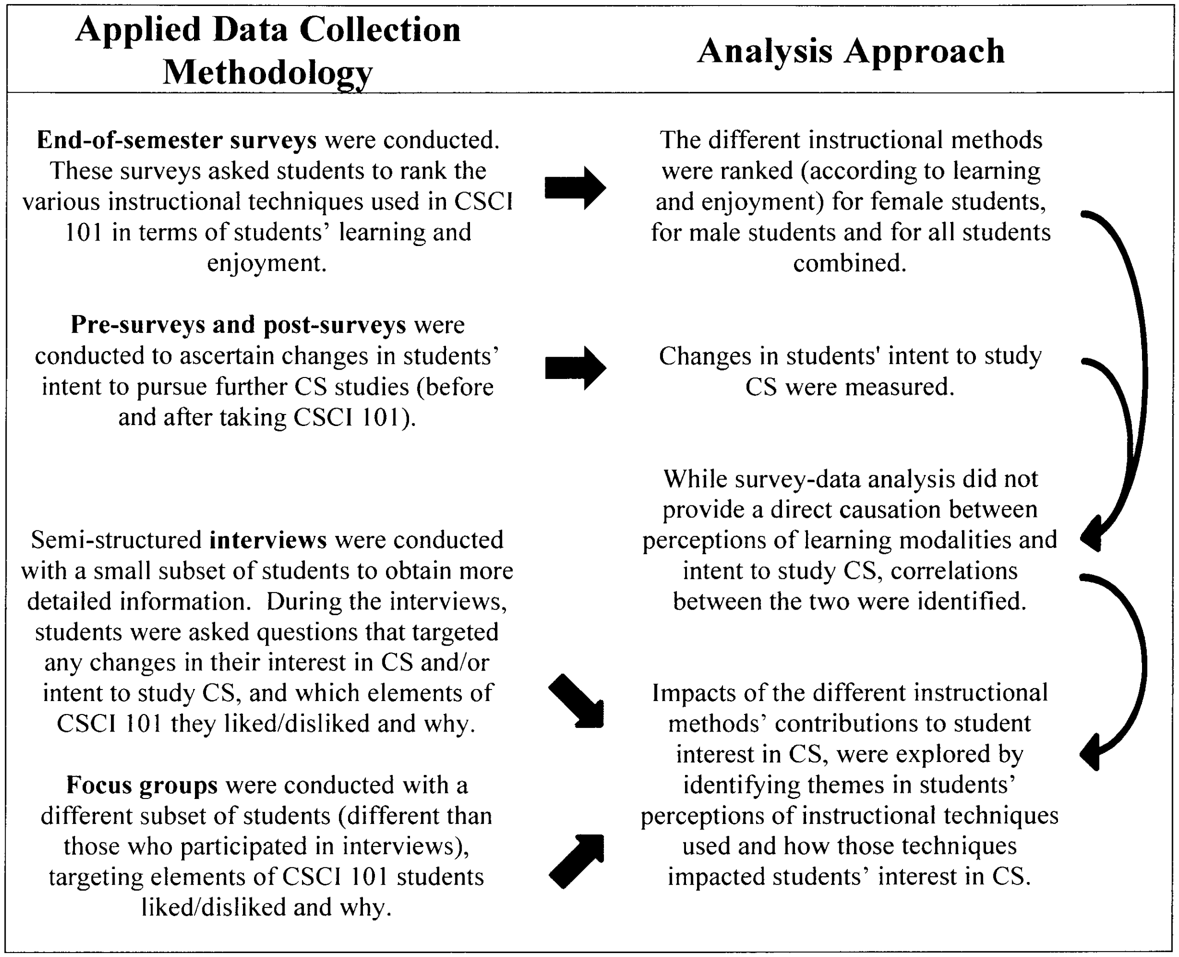

Figure 3.2. Analysis approaches related to data collection for investigating how students rank instructional methods used in CSCI 101.

Interest (ASI), taking additional CS courses without pursuing a CS major/minor/ASI, or none (no additional CS). They were permitted to make multiple selections so as to select all options they were considering. The same question was asked after students had completed CSCI 101 as well, to identify students' changes in intentions for further studies in CS. The highest level of study that a student selected both at the beginning and end of the semester were noted. Changes in students' highest level of interest, from the pre-survey to the post-survey, were then determined. Whether a student gained interest, retained interest, retained *no* interest, or lost interest in a CS major, was first determined based on whether or not a student selected "Major" on the pre-survey and on the post-survey. For students who had no change in their intent to pursue a CS major, a further determination of whether the student's interest generally increased, decreased, or stayed the same, was made based on changes in other categories. For example, if a student indicated considering a minor at the time of the pre-survey, but was only considering taking additional courses at the time of the post-survey, it was determined that the student had a decrease in interest. Separate evaluations were completed for students who entered the course as CS majors and for students who entered the course with an undeclared major or having declared a different major, to investigate retention and recruitment findings separately. That is, retention success was determined based on whether students who entered as CS majors retained their interest in majoring in CS; recruitment success was determined based on changes in all other students' intent to major in or otherwise study CS. Students' status regarding declared major upon entering CSCI 101 was determined based on their self-reported declared major(s). In cases where students did not report their major, information was obtained from the registrar.

Further details regarding why students learned from and enjoyed specific instructional components were explored through interviews and focus groups.

3.3.2 Analysis of Formal Learning Group Impacts

To explore the impacts that learning groups in CSCI 101 had on female students in terms of their perception of, excitement about, and intent to major in CS, students were asked at the end of the semester whether learning groups had an impact on their intent to study CS, and how they perceived learning groups compared to other more traditional learning methods. Furthermore, changes in students' perceptions of computing, intent to major in CS, and perceptions of learning groups, were measured through pre/post surveys. Figure 3.3 summarizes the specific analysis methodologies that were used for each type of data collection, as well as the flow of analysis. Additionally, specific analysis techniques are discussed below.

Qualitative data were collected regarding students' perceptions of learning groups through a survey that was given at the end of the semester. Students' responses to the question "Did working in learning groups have any impact on your intent to pursue further studies in Computer Science?" were categorized/coded first as "no" (learning

Applied Data Collection Methodology	Analysis Approach
Pre-surveys and post-surveys were conducted to ascertain changes in students' perceptions of formal learning groups, perceptions of computing, and intent to pursue further CS studies (before and after taking CSCI 101).	Changes (numerical differences in Likert responses) in individual students' perceptions of learning groups, CSCI 101, and computing in general, as well as students' intent to study CS were measured.
End-of-semester surveys were conducted. These surveys include open-ended questions related to students' perceptions of formal learning groups in CSCI 101, including how learning groups compare to traditional instructional methods, and any impact learning groups may have had on their intent to study CS.	Responses to open-ended questions regarding learning groups were categorized and types of responses were gathered to ascertain themes and patterns in students' perceptions.
	While survey-data analysis did not provide a direct causation between effects of learning groups and interest in CS, possible correlations between the two were made.
Semi-structured **interviews** were conducted with a small subset of students to obtain more detailed information. During the interviews, students were asked questions regarding their perceptions of learning groups in CSCI 101, including which aspects of learning groups they liked and disliked, and impacts learning groups may have had on their intent to study CS.	Impacts of learning groups, and learning groups' contributions to student interest in CS, were explored by identifying categories of responses to questions about experiences with and perceptions of learning groups.
Focus groups were conducted with a different subset of students (different than those who participated in interviews) to collect additional information related to students' perceptions of learning groups.	
	Notes: * All data were compiled for female students, for male students, and for all students combined. * Categories (such as those developed for survey responses) were generated for all students (i.e., the student groups were not separated for the purpose of generating response categories).

Figure 3.3. Analysis approaches related to data collection for investigating the impact of learning groups on female students in terms of their reported perceptions of CS.

groups did not have impact on intent to study CS), "yes" (learning groups did have impact on intent to study CS) or unanswered/unclear. In examining the "yes" responses to determine whether students who reported an impact from learning groups experienced a positive or negative impact, responses were further categorized in terms of positive vs. negative impact (or a combination of both), where "positive" was defined as an indication that the learning groups had a positive impact on the student's intent to study CS (i.e., the student had more interest in studying CS), and "negative" was defined as an indication that the learning groups had a negative impact on the student's intent to study CS (i.e., the student had less interest in studying CS). Additional categories were developed for reasons behind impacts, as well as specific benefits of and problems with learning groups, that students reported in response to this question. Codes were assigned to all students' responses based on these categories.

Students' responses to the question "How do you think learning groups compare to traditional learning methods (e.g., lecture and textbook)?" were categorized first as positive (defined as an indication that learning groups were preferred over other methods), as negative (defined as an indication that other methods were preferred over learning groups), or as conditional (defined as an indication that learning groups were positive given a certain condition) or both (defined as an indication that learning groups had both advantages and disadvantages compared to other methods). Categories were developed to describe students' responses, including specific benefits of and problems with learning groups, as well as conditions for success in learning groups.

Changes in students' perceptions of computing in general and of learning groups were measured through comparisons of pre/post survey Likert responses (see section *3.3 Data Analysis* for the analysis technique that was used to analyze such data). Changes in intent to major in CS were also measured (see section *3.3.1 Analysis of Instructional Method Impacts* for details on the analysis technique used).

Additional explorations into students' perceptions of learning groups were obtained through interviews and focus groups, as well as an open-ended survey question regarding general comments on learning groups for which response categories were developed and responses were coded.

3.3.3 Analysis of Learning Group Formations

CSCI 101 uses formal learning groups, in which students are placed for several weeks in a team of three to four other students with whom they discuss learning group assignments (i.e., teach one another material they have learned through completing assignments on their own) and solve problems together. Each student is placed in three to four different groups throughout the semester. During the Spring 2011 semester, there were two different sections of CSCI 101 in which students were enrolled (with the same instructors, same timeline for instruction, identical content/assignments/assessments, etc.), but the learning group data were not differentiated for analysis purposes in this study. During each round there were 20 or 21 groups spread across the two sections of the course. To identify what approaches to formal learning groups are most effective, including which group compositions may have potential to improve students' experiences with learning groups, students were asked to answer questions about their individual groups. Questions were designed such that responses would reflect students' learning experiences with each of the different groups they participated in, including whether the group promoted positive outcomes such as creativity, confidence in contributing to group work, and motivation to study CS, as well as whether the group was free of conflicts such as disagreements. Students were asked to rank their groups in terms of both effectiveness and inclusiveness (i.e., how included the groups made them feel in the teaching and learning process). Students were also asked to provide details on why, in their opinion, certain groups were effective, ineffective, inclusive or less inclusive.

To investigate the impact that specific learning group formations had on female students' reported learning experiences with formal learning groups, groups that appeared to be beneficial to female students' perceptions of working in groups were identified; properties of those groups were then ascertained. Figure 3.4 summarizes the specific analysis methodologies that were used.

First, groups that were considered to provide a generally positive experience for female students were identified. Students' responses to Likert questions (regarding each of their groups) were assigned numbers (0 through 3, where 0 represents "Strongly Disagree" and 3 represents "Strongly Agree"). A "success" number was calculated for each student, for each group; the "success" number was simply the sum of the Likert

Applied Data Collection Methodology	Analysis Approach
Learning group-specific surveys were conducted. These surveys included questions related to specific groups and aspects of each group's dynamics (Likert-type questions were asked about each group in which a student had participated throughout the semester).	Groups that were successful in different ways for female students were identified. First a group was deemed successful based on whether students ranked the group highly against other groups as "effective" and "inclusive." Second, traits of a group, as reported by its members, were considered in identifying groups that promoted fun, learning, confidence, motivation, etc.
End-of-Semester survey were also conducted, in which students were asked to rank the different groups they participated in based on the groups' effectiveness and inclusiveness, as well as explain why different groups were more/less effective/inclusive.	Group formation patterns (combinations of group members' traits) that appeared to be common in groups that were beneficial in various ways for female students were identified. Categories of responses to questions about experiences with particular groups were identified.
Traits of students (gender, grade level, major and course performance) were identified through **background info surveys** and **course assessments**.	Impacts of specific learning group formations on female students' learning experiences were explored by considering patterns of group formations and qualities that had particular outcomes according to survey and interview data.
Semi-structured **interviews** were conducted with a small subset of students to obtain more detailed information. During the interviews, female students were asked what combinations of males and females in groups help them to be more comfortable participating. **Focus groups** were conducted with a different subset of students to collect additional information related to which group formations students perceived as most and least effective.	Notes: * Categories / codes were developed based on all students' responses (i.e., there were not separate codes for female students' comments and male students' comments).

Figure 3.4. Analysis approaches related to data collection for investigating learning group formations.

score for each of the eight statements used to evaluate the group (e.g., "I learned a great deal from this group," or "This group motivated me."). While there is no specific significance to this "success" number, a higher number typically indicated a group that a student felt s/he generally benefited from more (e.g., if a student answered "Strongly Agree" to all questions, the result was the number 24), whereas a lower number typically indicated a group that a student felt s/he benefited from less (e.g., if a student answered "Strongly Disagree" to all questions, the result was the number 0). A student's assessment of a particular group was also indicated by how the student ranked that group against other groups in terms of how much s/he learned from the group and how much s/he felt included in the teaching and learning process with that group. Since there were four rounds of groups that occurred throughout the semester, the ratings were "Most Effective," "2nd Most Effective," "2nd Least Effective" and "Least Effective"; a similar rating scheme was used for the student's rank of groups as inclusive.

A list was created with all groups that at least one female student indicated as having *all* of the following properties:

- the given Likert score for each category (e.g., "In this group I felt comfortable contributing," "I got excited about computer science with this group," and "This group made me feel confident in my abilities,") was either "Agree" or "Strongly Agree,"
- the "success" number (as described above) was greater than 18 (i.e., she selected a rating of "Strongly Agree" for at least three categories),
- she ranked the group as either her most effective or 2nd most effective group, and
- she ranked the group as either her most inclusive or 2nd most inclusive group.

Although the criteria used to identify groups that were generally positive for female students were subjective, they provided a set of groups that could be considered to identify types of group formations that appeal to or present positive experiences for female students.

From the list of 14 groups that appeared to work well for female students, several types of combinations were compared and summarized to identify patterns of group formations that were common in those groups. First, the number of male and female students participating in a group were considered. Second, combinations of different levels of academic progress (i.e., freshman, sophomore, etc.) were examined. Experience levels were also assessed; students' majors and level of progress in school were combined to make a determination regarding students' prior experience with CS (i.e., junior and senior CS majors were considered to have more experience). Finally, combinations of students based on their final grades for the course (performance indicators) were reviewed. The entire set of group formations was not analyzed to determine the overall frequencies of various combinations, so the analysis was completed solely for the purpose of identifying examples of common formations of groups with which female students had positive experiences.

Students' perceptions of their experiences with specific groups were measured through open-ended survey questions that inquired about properties of the groups that students felt were more/less effective/inclusive. Responses were categorized and summarized (see section *3.3 Data Analysis* for the analysis technique that was used to code open-ended survey responses). Each component of a student's response was generally categorized as a *group formation property* (e.g., all students were freshmen, or students varied in levels of CS knowledge/experience), a *property or tendency of the group* (e.g., all members of the group got along well, or the group did not discuss learning group assignments), a *trait of one or more members of the group* (e.g., member(s) were knowledgeable or member(s) were condescending), an *action of one or more members of the group* (e.g., member(s) listened to and valued others' input, or member(s) came unprepared), a *feeling the student experienced* (e.g., felt comfortable participating, or felt contributions were not needed or heard), or a *property of the timing of the group* (e.g., took place at the beginning of the semester). Responses were further identified by more specific categories (i.e., the specific trait of the member(s), the specific timing of the group, etc.)

Additional insights into students' experiences with specific combinations of students in learning groups and properties of learning groups were explored through the analysis of interview and focus group data.

CHAPTER 4 FINDINGS

Surveys that included questions on background information, perceptions of Introduction to Computer Science (CSCI 101) at CSM and computing in general, intent to pursue studies in CS, and learning groups, were given in Spring 2011, the second semester that CSCI 101 was offered at CSM. Interviews and focus groups were also conducted to gather additional feedback from students regarding their experiences in CSCI 101.

Many of the survey questions were asked at the beginning and end of the CSCI 101 semester in order to ascertain changes in what students reported before and after taking the course. There were 15 female students (out of the 20 initially enrolled in the course) and 61 males (out of the 82 initially enrolled in the course), or a total of 76 students, who took both surveys. An additional four female students and 17 male students took the pre-survey (and therefore provided background information). Two male students who had not taken the pre-survey did take the post-survey and therefore answered some questions related to instructional methods and learning groups in particular. Table 4.1 shows the number of students who completed both, only one, or neither one of the surveys.

Table 4.1. Distribution of students who took the pre-survey, post-survey, both surveys, or neither survey.

	Both Pre and Post	**Pre Only**	**Post Only**	**Neither**	**TOTAL**
Females	**15**	4	0	1	20
Males	**61**	17	2	2	82
All Students	**76**	21	2	3	102

Many students completed group-specific surveys, but not all students completed a survey for each group in which they participated. Four female students and four male students participated in interviews; eight female students and six male students participated in focus groups (two focus groups per gender).

Findings, including descriptive statistics, summaries of qualitative data, and synthesized interview and focus group data are outlined below.

4.1 Changed Intent to Study CS and Perceptions of Computing

A key to determining whether recruitment and retention have been successful is to measure changes in students' intent to study or major in CS and their perceptions of computing in general.

Intent to study CS: At the beginning and end of CSCI 101 students were asked to indicate if they were considering a CS major, minor or Area of Special Interest (ASI), taking additional courses in CS without majoring/minoring, and/or taking no additional CS courses. Changes from the pre-survey to the post-survey were noted for each student regarding his/her highest level of interest in studying CS (e.g., "minoring in CS" was noted as the student's highest level of interest if s/he indicated an interest in a CS minor *and* an interest in taking additional CS courses without majoring or minoring). Pre- and post-survey responses were available for 75 students, 34 (four females and 30 males) of whom were CS majors coming into the course, and 41 (11 females and 30 males) of whom were undeclared or non-CS majors.

To determine whether students were retained in the CS major after taking CSCI 101, all students who entered CSCI 101 as CS majors were considered. All but one freshman male student, of the 34 CS majors entering the course, were still interested in pursuing a CS major according to their responses on the post-survey.

To determine whether recruitment was successful, students who were not declared as CS majors at the beginning of CSCI 101 were considered. Table 4.2 displays the number of students who gained, had no change in, and lost interest in a CS major, respectively. The number of students who had no change in interest in a major was further broken down in Table 4.2 into students who retained an interest (reported an interest in majoring in CS on the pre-survey and post-survey) and those who retained no interest (did not report an interest in majoring in CS on either survey). Additionally, for the set of students who had no interest in a CS major, details are provided regarding how many students had other increases or decreases in their interest in studying CS (e.g., a student was considered to have increased his/her interest in studying CS if s/he indicated taking additional CS courses as the highest level of interest on the pre-survey but indicated interest in a CS minor on the post-survey). Note that no female students lost interest in a CS major, but one female student gained an interest in the major after taking CSCI 101.

Table 4.2. Recruitment findings: Changes after taking CSCI 101 in interest in studying / majoring in CS (students who did not enter CSCI 101 as CS majors).

Gained Interest in CS Major			(3 Students: **1 Female** / 2 Males)
Did Not Change Interest in CS Major	Retained Interest in CS Major		(10 Students: **3 Females** / 7 Males)
	Retained NO Interest in CS Major	Increased Interest in *Studying CS*	(4 Students: **2 Females** / 2 Males)
		Did Not Change Interest in *Studying CS*	(15 Students: **4 Females** / 11 Males)
		Decreased Interest in *Studying CS*	(7 Students: **1 Female** / 6 Males)
Lost Interest in CS Major			(2 Students: **0 Females** / 2 Males)

The presence of upperclass students in CSCI 101 created a participant pool that did not necessarily match the target population of this study (i.e., freshman and sophomore level students who are at the beginning of their academic careers). Results of the recruitment and retention investigations which include *only students in the target population of this study* are provided next. There were 54 freshman or sophomore students (7 females and 45 males) who provided pre-survey and post-survey responses regarding interest in pursuing CS studies. Of those students, 24 (2 females and 22 males) were declared CS majors upon entering CSCI 101 whereas 28 (5 females and 23) were either undeclared or had declared a major other than CS prior to entering CSCI 101. As stated previously, all but one CS major (a freshman male) continued interest in a CS major after taking CSCI 101. Table 4.3 parallels Table 4.2, but only includes the target population of this investigation (freshman and sophomore students).

Table 4.3. Recruitment findings for *freshman/sophomore level* students: Changes after taking CSCI 101 in interest in studying / majoring in CS (freshmen/sophomores who did not enter CSCI 101 as CS majors).

Gained Interest in CS Major			(2 Students: **0 Females** / 2 Males)
Did Not Change Interest in CS Major	Retained Interest in CS Major		(10 Students: **3 Females** / 7 Males)
	Retained NO Interest in CS Major	Increased Interest in *CS*	(1 Student: **0 Females** / 1 Male)
		Did Not Change Interest in *Studying CS*	(8 Students: **1 Female** / 7 Males)
		Decreased Interest in *Studying CS*	(5 Students: **1 Female** / 4 Males)
Lost Interest in CS Major			(2 Students: **0 Females** / 2 Males)

Perceptions of computing: Students were asked before and after taking CSCI 101 to rate various statements about computing in terms of their level of agreement with the statements. There were not sufficient data to assess changes in students' perceptions of computing. Changes between pre-survey and post-survey responses are summarized in *Appendix B Students' Changed Perceptions of Computing.*

4.2 Perceptions of Instructional Methods in CSCI 101

Surveys, as well as interviews and focus groups were used to collect data regarding students' perceptions of instructional methods used in CSCI 101. Survey results, as well as findings from interviews and focus groups are detailed in the upcoming sections.

4.2.1 Related Survey Results

Students were asked to rank five different instructional methods used in CSCI 101 in terms of how much they learned from the methods, as well as how much they enjoyed them. The five methods included formal learning groups, two traditional learning methods (reading a textbook and observing lecture), one method commonly used in CS instruction (programming), and one less commonly used method that only took place a few times during the semester (playing/watching content-related computer games). While the learning methods were not used for the same amount of time in class and the different methods were not used for learning identical material, students' perceptions of how much they enjoyed and learned from the various methods may provide insight into which types of instructional methods promote students' interest in participating in a course. Figures 4.1 and 4.2 show the percentage of female students, male students, and all students combined, who ranked each learning method as the one from which they *learned most*, and which they *enjoyed* learning from the *most*, respectively.

As mentioned previously, the presence of junior and senior level students in CSCI 101 led to findings that may not necessarily be representative of the target population of this study. Findings related to how students rank the various learning methods in terms of their learning and enjoyment are displayed specifically for students in the target population in Figures 4.3 and 4.4.

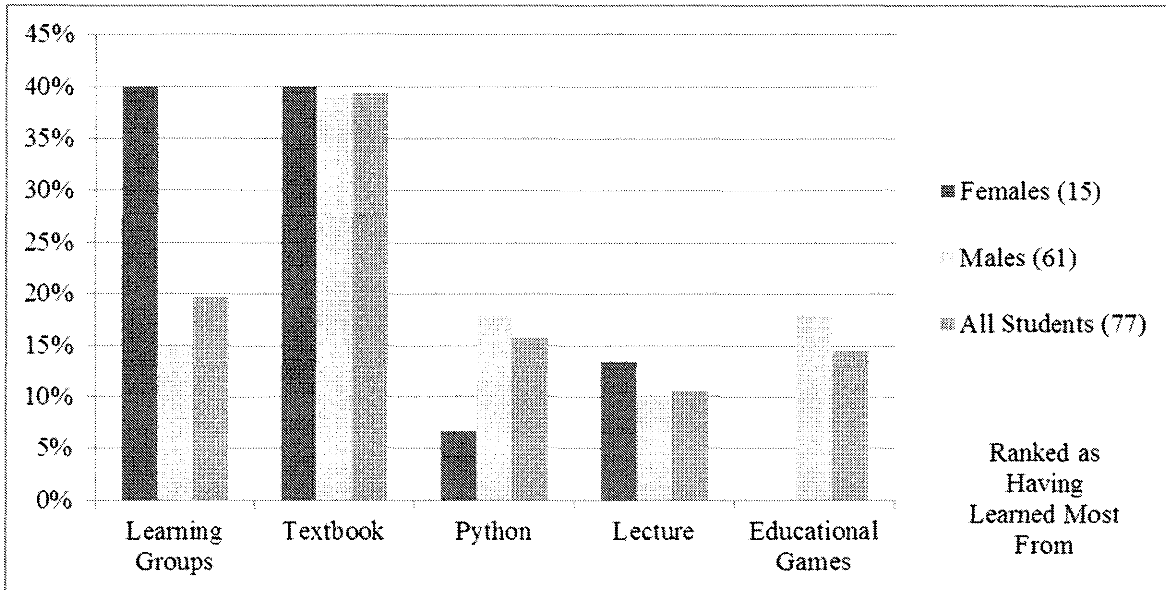

Figure 4.1. Percentage of students who ranked each of the five learning methods used in CSCI 101 as the one they *learned most from.*

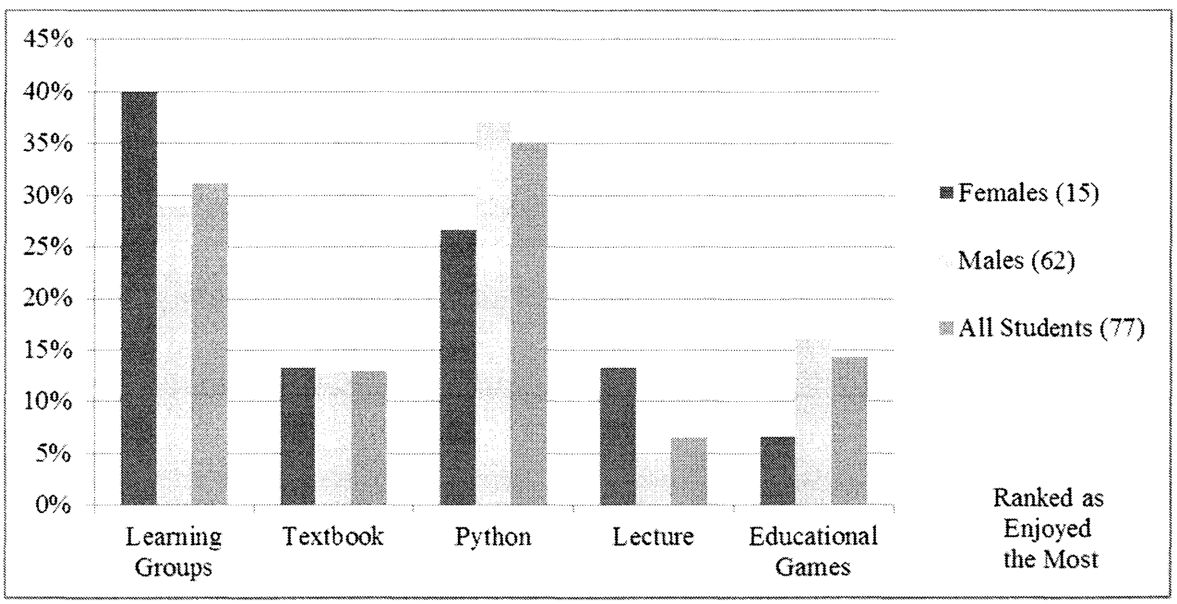

Figure 4.2. Percentage of students who ranked each of the five learning methods used in CSCI 101 as the one they *enjoyed the most.*

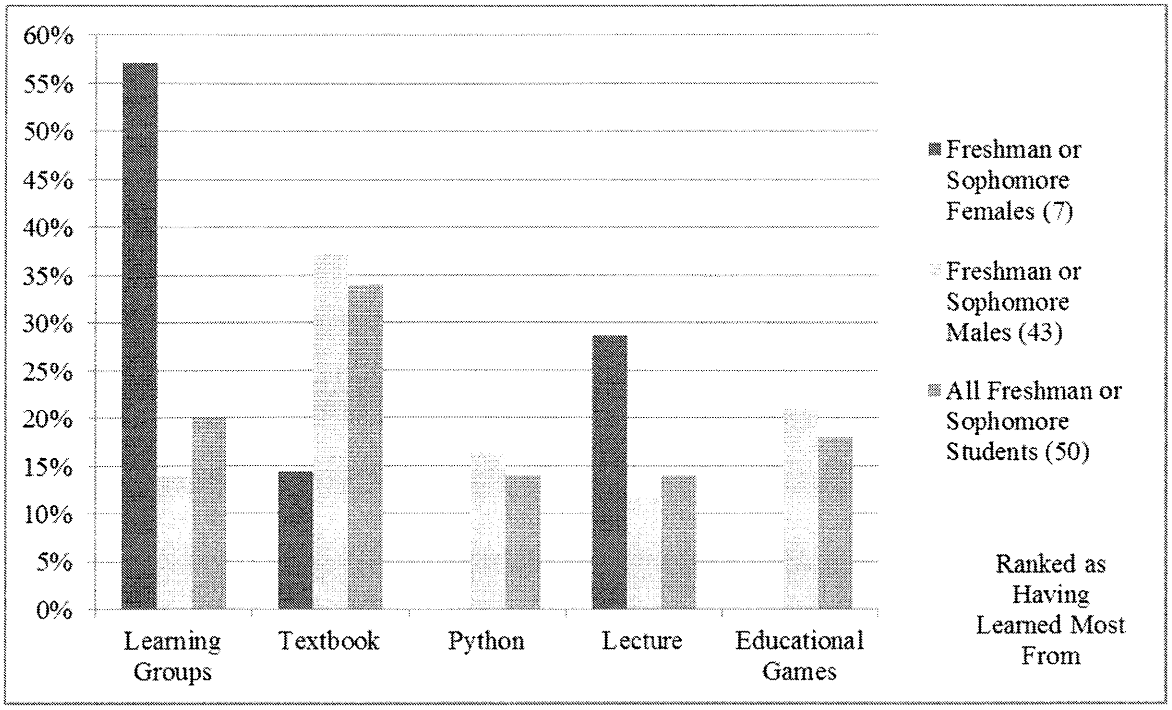

Figure 4.3. Percentage of *freshman/sophomore level* students who ranked each of the five learning methods used in CSCI 101 as the one they *learned most from*.

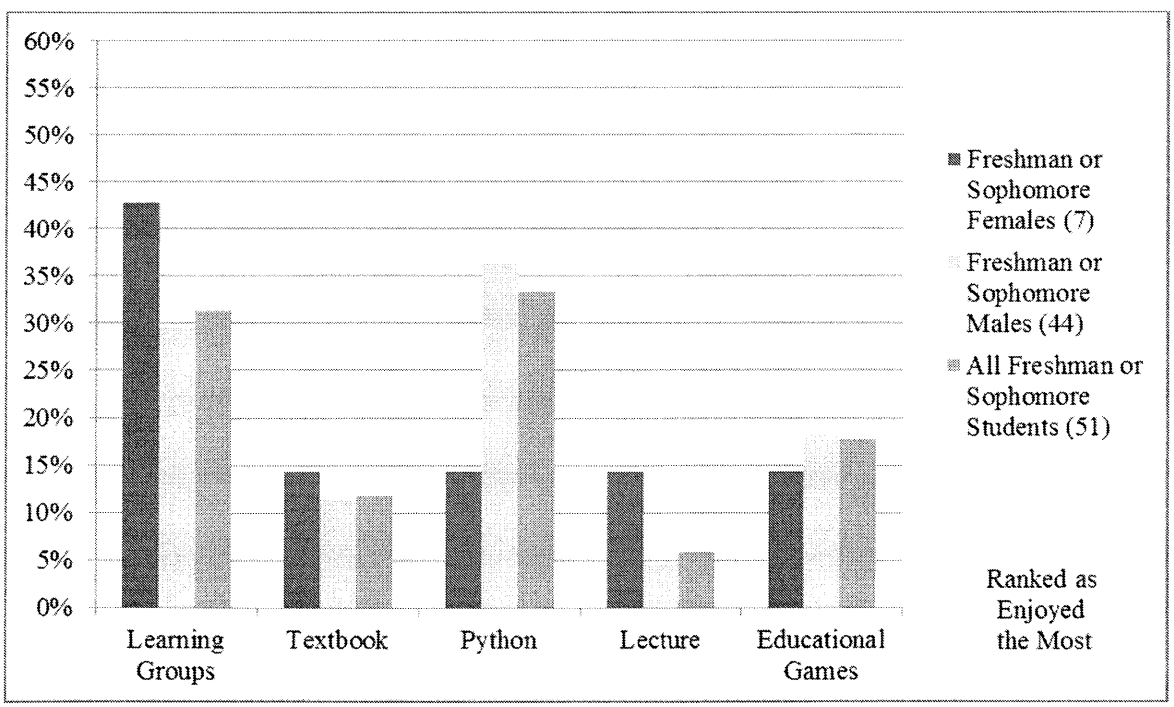

Figure 4.4. Percentage of *freshman/sophomore level* students who ranked each of the five learning methods used in CSCI 101 as the one they *enjoyed the most*.

The set of female students in the freshman/sophomore population was small (i.e., only seven female students), but the results for the population of underclass students were relatively similar to those of the whole class including the upperclass students. The primary exception to the general similarities was that learning groups appeared to be ranked highest for learning by a larger percentage of female underclass students.

4.2.2 Related Interview and Focus Group Findings

To garner additional details regarding students' perceptions of instructional components of CSCI 101, semi-structured interviews were conducted with a small subset of students and focus groups were conducted with a different subset of students (see sections *3.2.3 Interviews* and *3.2.4 Focus Groups* for information regarding data collection methods used for interviews and focus groups, respectively). Interview and focus group questions targeted students' perceptions of instructional methods within CSCI 101 (i.e., which ones they liked/disliked most and why). Individual interviews also included questions that targeted any changes in students' interest in CS and/or pursuing CS studies.

Aspects of CSCI 101 that students liked and disliked: During individual interviews, students were asked which aspects of CSCI 101 they liked most and which aspects they disliked most; they were also asked for explanations regarding their responses. Focus group discussions were guided using the same questions. In both the interviews and focus groups, the questions were open-ended (i.e., students were simply asked to identify which aspects of the course they liked or disliked, rather than being asked to rank or discuss specific instructional methods such as lecture or learning groups).

There were a variety of responses regarding which elements of the course the students liked; responses included instructional techniques used in CSCI 101 (i.e., lecture, learning groups, textbook, programming, and computer games), specific aspects of some of the instructional techniques, and specific content or topics that were taught in the course (e.g., binary number systems or operating systems).

Each instructional technique used in the course was remarked upon by at least one student in either a focus group or an interview, as an aspect of CSCI 101 that the student liked. In one of the female focus groups, Python programming was discussed most as an instructional technique that students enjoyed, whereas in the other female focus group, learning groups were discussed most and one student mentioned electronic educational games. Learning groups were also discussed in one of the male focus groups as well as by several female students in individual interviews; learning groups appeared to be identified more often than the other instructional techniques by the students who participated in interviews and focus groups. In the other male focus group, the instructional techniques that were referenced were lecture and reading the textbook.

Responses related to learning groups as a construct that was "liked" included reasons such as the need to work harder as a result of the group's dependence on one another, the ability to ask questions in a small group setting, meeting people, etc.

> <u>Students reported that learning groups foster the need to work harder as a result of the group depending on them</u>
>
> "I really actually liked learning groups. At the beginning I was really skeptical about how my grade would partly depend upon other people's scores and that kind of worried me slightly, but I found that it was really good to be able to talk about a certain subject or certain content with other people to see their opinions, and at the same time you have the responsibility that you need to get this work done so that you could teach others. I think it's really effective actually in learning."
> (Interview: Female, Senior, Non-Major)
>
> "I liked the learning groups, but I think one thing about them was obviously no one really likes reading the text book, so sometimes it was kind of self taught reading the text books and gathering all the information on your own, but at the same time, like, you were encouraged to do that 'cause you didn't want to let your teammates down."
> (Interview: Female, Junior, Non-Major)
>
> <u>Students reported that learning groups give the ability to ask questions in a small group setting</u>

> "I liked the learning groups 'cause that was nice to get to talk to other students and ask questions instead of bothering the whole class which is what it usually feels like when you ask a question." (Interview: Female, Junior, Non-Major)
>
> "I liked the groups, since, I mean, it's a big class and [instructors] can't always teach us something one-on-one whereas if you're in a little group and you're struggling with [a topic], [student] over here can teach it to me."
> (Focus Group: Female, Junior, Non-Major)
>
> <u>Students said they liked learning groups because of meeting people</u>
>
> "I liked that we were able to work in learning groups because we got to meet people. … It was cool to talk and interact with people."
> (Focus Group: Male, Sophomore, Non-Major)
>
> *Directly following the above comment in a focus group, another student commented* "Yeah, it was great, it was nice working with people of different skill levels and knowledge levels, because uhh, you learned some things, you taught some things. It was fun."
> (Focus Group: Male, Junior, CS Major)
>
> "I really enjoyed meeting a lot of the people in my class, and most of them, I'm still friends with all of them."
> (Focus Group: Female, Junior, Non-Major)

The students who mentioned electronic games, lecture, and textbook as constructs that they liked stated the following:

> <u>One student reported that the electronic games were fun and represented an example of an application of programming</u>
>
> "I really like the games, like the Wii protocol game and the Binary Blaster. I learned better when I could … make it into a little competition or something … and since it's all programmed on a computer, it was interesting to see you could learn binary on the computer, from something that someone had to program forever on the computer, so, it's just interesting."
> (Focus Group: Female, Sophomore, Non-Major)

> <u>Two students reported that lecture and/or textbook promoted more learning</u>
>
> "Even though I had multiple groups that contributed a lot of information, I got most value out of actually reading the book, and listening to the professor lecture."
> (Focus Group: Male, Senior, Non-Major)

The female focus group that discussed Python programming as one of the instructional components of CSCI 101 which they liked, identified reasons such as ease of use in comparison to other programming languages. All but one of the focus group members had taken other programming courses in the past and indicated that Python was easier than the other languages.

> <u>Students reported that Python was easier to learn than other programming languages</u>
>
> "[You] learned [C++], and then you learned MATLAB and then you learned Fortran and then you come to Python and then you're like, wow this is like so *intuitive*, it's really easy." (Focus Group: Female, Senior, Non-Major)

Students also reported certain content areas, or topics, as aspects of CSCI 101 that they liked. For example, several female students mentioned binary number systems (e.g., "I definitely liked the binary part because that kind of combined math and the computer science and that was something interesting to me, and just like the whole like idea of how you can represent things using numbers"), one student mentioned operating systems, and one student mentioned computer basics (e.g., "I liked figuring out how the machine worked 'cause I had no idea how that works, I just know that I can type a program and then it works.")

There was variation in the responses that students gave regarding elements of the course they *disliked*; responses included instructional techniques used in CSCI 101 (primarily learning groups and Python programming), and specific implementation concerns surrounding those instructional techniques. In the female focus group that indicated Python programming as one of the aspects they generally liked, the topic of too much homework in the form of learning group assignments arose as an aspect that many of those students disliked.

<u>Students identified the frequency of learning group assignments (homework) as problematic</u>

"I didn't like the way that the homework was set up, where you had three different homework assignments a week. … I would have rather had an assignment that you turned in at the end of the week rather than three little ones throughout the week." (Focus Group: Female, Junior, Non-Major)

"Yeah, I agree. I forget to do them a lot, 'cause it'd be like every other day, so I'd be like 'Oh, I'll put it off until tomorrow' and then the next day I'd have something big in a different class too, and I'd just forget, like end up doing it in the morning [before class]."
(Focus Group: Female, Freshman, Undeclared Major)

"It might be better if you did it where you assign one on Monday so people had until Friday to do it … 'cause then it would just give you more time."
(Focus Group: Female, Senior, Non-Major)

Other students were concerned about the amount or advanced nature of the Python assignments:

<u>Python assignments were reported as too advanced for beginning programmers, too frequent, or needing more explanation from instructors</u>

"To teach the Python, you just set tutorials up, so people had to teach themselves, which if you've never learned a programming language before could be [*pause*]"
(Focus Group: Female, Junior, Non-Major)

Another female student in the focus group completed the previous student's comment: "Daunting."
(Focus Group: Female, Sophomore, Non-Major)

"I didn't like honestly how many programming assignments there were because … when there were like two in two weeks it just got a little overbearing compared to my other classes."
(Interview: Female, Sophomore, Non-Major)

> "With Python, I liked the tutorials 'cause it kind of teaches you how to do it, but the key word there for me is *kind of* teaches you. I feel like a little bit more in the class would do more for me with those assignments."
> (Interview: Male, Sophomore, Non-Major)
>
> "We kind of like jumped in, we got general tips about Python and we were just kind of told to go at it."
> (Focus Group: Male, Freshman, CS Major)

In the female focus group in which learning groups had been discussed as an aspect of the course that students liked, there were also numerous comments regarding specific aspects of learning groups that were problematic. Other students reported concerns with learning groups as well.

> <u>Some students reported that they did not like certain groups because teaching and learning did not occur, or they had to teach themselves anyway</u>
>
> "I liked the first learning group, but I didn't like the learning groups after that 'cause we didn't share, like 'cause we each had our homework assignments, and in my first group the next morning we'd actually teach the groups, or the other kids in our group, what we learned. We didn't do that in any of my other learning groups, so I had to teach myself everything, which took forever, and was awful and it just didn't work."
> (Focus Group: Female, Sophomore, Non-Major)
>
> *In response to the previous comment, a student stated*: "I agree. ... If you had a bad group, it was really bad."
> (Focus Group: Female, Junior, Non-Major)
>
> "[Sometimes my group members] wanted to know, like, why I just couldn't understand that, and I was like, OK, well, apparently I'm gonna go read the book again."
> (Focus Group: Female, Sophomore, Non-Major)
>
> *In a different focus group with male students, another student indicated similar concerns with learning groups*:
> "I like lecturing a lot better. I felt like LGAs should be a study group outside of class... . I think, a lot of people just relied on other people to teach them instead of learning it themselves." (Focus Group: Male, Senior, CS Major)

> <u>Some students reported a desire for more lecture mixed in with learning group work</u>
>
> "I feel like there should be more lecture time, maybe instead of solely just doing [learning group assignments] on your own, because sometimes if you end up getting questions about the same things over and over you miss a topic or two in actually doing the work yourself. So, a little more lecture." (Interview: Female, Junior, Non-Major)
>
> <u>Other students generally did not like learning groups</u>
>
> "I wasn't a huge fan of the learning groups but I felt like when we did those we were able to cover more topics, but not being able to go as much in depth as a regular lecture would." (Interview: Male, Sophomore, CS Major)

Individual students' changes in interest in CS and pursuing CS studies: To investigate whether the course may have had any impact on students' interest in studying CS, interviewees were asked if they had any changes in their interest in CS and pursuing CS studies after taking CS 101, and if so, if there were any particular elements of the course that had an impact.

When students were asked if their level of *interest in computing in general* had changed after taking CSCI 101, many students (all but one female student and one male student) indicated a positive change. The other two students reported no change, indicating that they had previously been interested in the field and that they were now equally interested as they had been before taking the course. Common reasons for an increased interest in computing were the breadth of topics and the elementary nature of the material covered in CSCI 101 (e.g., learning more than simply programming or receiving an overview of how a computer works). When female students were asked if their *interest in pursuing CS studies* had changed after taking CSCI 101, their responses typically paralleled their responses to the question regarding their interest in computing in general in that they either had no change since they would continue pursuing CS studies or had an increase in their intent to take CS courses. All but one of the male students reported that there was no change in their intent to study CS because they were already interested in pursuing CS studies before they took CSCI 101. Varying elements of the course were cited when students were asked whether any instructional aspects of the course such as lecture, learning groups, etc., had an impact on their changed interest levels. Lecture, learning groups and programming were all mentioned. Several examples of students' reports follow.

One female student (a sophomore student who was not a CS major at the beginning of CSCI 101) mentioned that she felt the course influenced her intent to major in CS.

> "Well I definitely think it has because I was first taking [CSCI 101] because my major didn't require chemistry and then I got into the class and it was like 'oh this is an even more interesting major than I thought,' and so I think the class actually changed my major."
>
> *She reported the following as a reason that her level of interest had changed*: "I've always had a love for computers and out of my family I was the one doing all of the tech stuff and I think, you know, just like being exposed to it more and seeing it as possibly a job in the future definitely was an interest."
>
> *When asked if any elements of CSCI 101 (e.g., learning groups, Python, lecture) had an impact on her changed level of interest, she responded*: "I think the lecture, a little bit, and then just the whole idea of the concept of programming was interesting to me."
> (Interview: Female, Sophomore, Non-Major)

A female student (a junior not majoring in CS) who reported an increased level of interest in computing, and somewhat of an increased interest in taking additional CS courses reported the following:

> *In regards to her interest in computing*: "I think it has, I mean before the class I was interested in it, but I didn't really know, like anything about, well anything about computers really, and I really enjoyed the class… . It was a nice introduction to everything and even though nothing really went too in depth but it kind of gave an overview."
>
> *The following dialog also occurred with this student*:
>
> > *Julie*: Do you think that you will take more CS classes in the future?
> > *Student*: I think so, yeah.
> > *Julie*: So are you a math major?

> Student: Yeah I'm in the applied math so I will be taking some of the computer classes also.
> ...
> Julie: So you will be [taking additional CS classes] by default?
> Student: Yeah, but now I feel more comfortable going into them, and hoping that I will enjoy them more than I was expecting.

> *Regarding instructional elements that had an effect on changed intent, she stated*: "I really liked the learning groups. … It was nice to see what people I was going to be around a lot more and kind of talk to them more on a more friendly level within the small groups as opposed to just the formal lecture where I probably wouldn't have talked to any of them." (Interview: Female, Junior, Non-Major)

A female student (a junior not majoring in CS, but taking additional CS courses) who indicated no change in her level of interest in computing or studying CS reported the following:

> *In regards to her interest in computing*: "Not really just because this is like my fourth computer science class. I've taken all the hard ones and went to the easy ones."
>
> *In regards to her interest in studying CS*: "Well I'm already pursuing it so I'll continue. I didn't change my mind away."
>
> *While she did not indicate any changes in her interest level, she stated*: "It was nice to go back to the very basics and how the computer actually worked instead of just the programming." (Interview: Female, Junior, Non-Major)

One of the male students was a sophomore CS major and reported no changes in interest level. He did not provide any additional information. There were two male students (both sophomore CS majors, one of whom only self-reported that he was a CS major but was not registered as a CS major), who indicated that their interest in CS as a field increased, but that their intent to study CS did not change since they were already invested coming into the course. One of the two male students provided a reason for his changed interest in computing and was as follows:

> "Uhh, I guess it's increased more, just learning all different kinds of computing. … We covered a lot of things but not a whole lot in depth so it kind of opened that up a little more."
>
> *When asked about specific instructional methods that may have had an impact on his change in interest level, he stated*: "No I don't think it's really impacted it at all really, just like I said just got more broad in terms of what there is to the [field]." (Interview: Male, Sophomore, CS Major)

The remaining male student (a sophomore who was not a CS major) who indicated that his interest in computing and in taking additional CS courses had both increased, reported the following:

> *In regards to his interest in computing*: "I got more interested in computer science after [CSCI 101] because I found the programming interesting even if I struggled some."
>
> *He further explained that the reason CSCI 101 increased his interest in pursuing CS studies was*: "Umm, the learning groups, I liked them mostly. The only thing I don't like is it kind of makes me a little bit lazier. … Well I guess Python pushed me a little more towards computer science, but really the uhh learning group portion."
> (Interview: Male, Sophomore, Non-Major)

Generally, male and female interviewees reported either positive changes in their interest in computing and/or intent to pursue CS studies, or reported no changes due to prior interests on which the course had no impact. While many of the interviewees and focus group participants reported learning groups and Python programming as aspects of CSCI 101 that they liked or disliked, there were no instructional methods used in CSCI 101 that emerged as reasons for changed levels of interest in CS in general or in studying CS.

4.3 Perceptions of Formal Learning Groups

Surveys, interviews, and focus groups were conducted to collect data pertaining to students' perceptions of formal learning groups as they were used in CSCI 101. Survey results, as well as interview and focus group findings are outlined in the next two sections.

4.3.1 Related Survey Results

To evaluate students' reported perceptions of formal learning groups in CSCI 101, comparisons of Likert responses on pre- and post-surveys were made to ascertain changes in students' perceptions of learning groups after taking the course. Moreover, students' open-ended survey responses, including how students report learning groups as compared with traditional instructional methods, and impact learning groups had on their intent to study CS, were categorized and summarized.

Perception of learning groups as fun (pre/post data): Students were asked to rate the following statement on a Likert-type scale on the pre- and post-surveys: "I will have fun / had fun working in formal learning groups in CSCI 101." Students were given a description of formal learning groups on the first day of the semester, prior to completing the pre-survey. The description included information regarding how much class time would be spent in groups, how students were expected to participate in the groups (e.g., the responsibility to come to class prepared and teach/learn from their peers), and how students' grades would be impacted by group performance (i.e., 10% of each student's course grade would be determined based on their group members' quiz grades). On average, students entered CSCI 101 with slightly positive expectations that learning groups would be fun (> 1.5 on the scale of 0 to 3) and left the course with slightly positive perceptions as well. Female students' ratings increased slightly after taking CSCI 101, while male students' ratings changed minimally. Specifically, the average change was an increase of 0.33 on the four-point scale for female students (an increase of 0.48 for freshman and sophomore female students only), whereas the average change for male students was a decrease of 0.08 (but an increase of 0.04 for freshman and sophomore male students only). Additionally, more female students showed a positive change than showed a negative change, whereas fewer male students showed a positive change than a negative change. Percentages of all female students and all male students who agreed (or disagreed) at the end of the semester that they had fun working in learning groups are displayed in Figure 4.5. Additionally, similar data are displayed for underclass students (freshmen and sophomores only) in Figure 4.6.

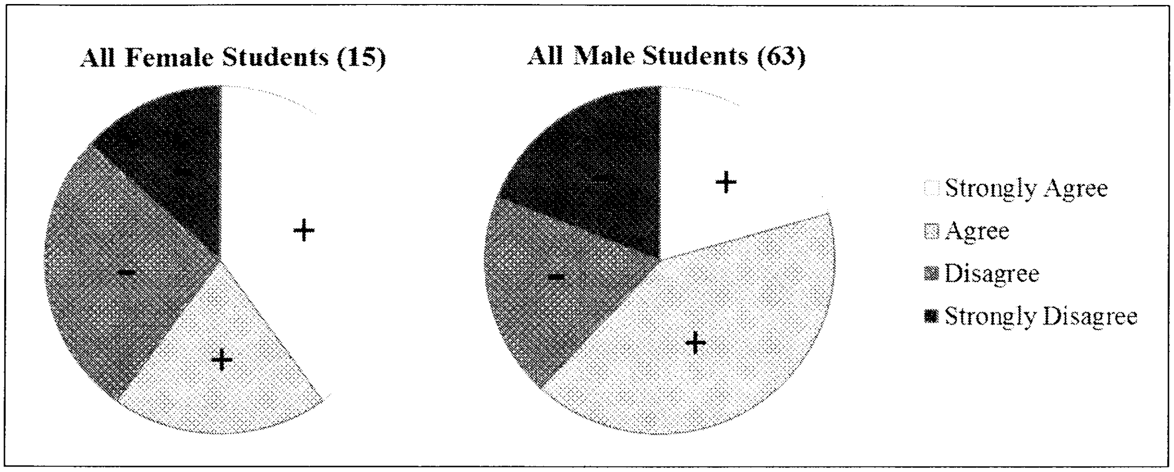

Figure 4.5. Students' responses to (agreement with) the statement "I had fun working in formal learning groups in CSCI 101" at the end of the semester.

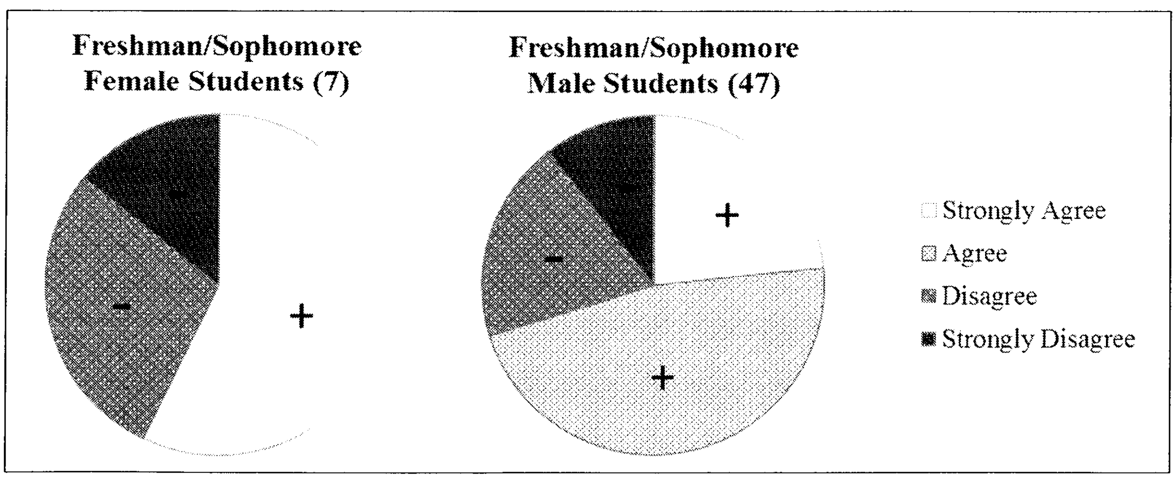

Figure 4.6. *Freshman/sophomore level* students' responses to (agreement with) the statement "I had fun working in formal learning groups in CSCI 101" at the end of the semester.

Impact of learning groups on intent to study CS: Impacts of learning groups, and learning groups' contributions to student interest in CS, were explored by identifying categories of responses to questions about experiences with and perceptions of learning groups. In a survey given at the end of the semester, students were asked the following question: "Did working in learning groups have any impact on your intent to pursue further studies in Computer Science?"

Students' responses were categorized as "no" (learning groups did not have any impact on students' intent to study CS), and "yes" (learning groups did have an impact on students' intent to study CS). Some responses were unanswered or unclear. Most female and male students indicated that learning groups did not have an impact on their intent to pursue additional CS studies. Table 4.4 summarizes responses for female students, male students, and all students combined.

Table 4.4. Student responses when asked if learning groups had an impact on intent to pursue further CS studies.

	Did Not Have Impact	Had Impact	Unanswered/ Unclear
Females (15)	10 (66.7%)	2 (13.3%)	3 (20.0%)
Males (63)	49 (77.8%)	8 (12.7%)	6 (9.5%)
All Students (78)	59 (75.6%)	10(12.8%)	9 (11.5%)

From students' "no" responses (i.e., responses indicating that learning groups did not have an impact on students' intent to study CS), several categories emerged as explanations. Those categories are presented in Table 4.5. The number of female and male students who reported each reason is also shown.

Table 4.5. Categories of responses that students indicated as reasons they experienced no impact on intent to study CS (as a result of working in learning groups).

Reason Indicated For Lack of Impact	**Number of Females**	**Number of Males**
Continuing CS studies anyway	3	16
Graduating	0	4
Not continuing CS studies anyway	0	4
Set in current [non-CS] major	2	2

In examining the "yes" responses (i.e., responses indicating that learning groups had an impact on intent to study CS) to determine whether those students experienced a positive or negative impact, the responses were further categorized as "positive" or "negative," or a combination. Students primarily indicated that learning groups had a positive impact on their intent to pursue CS studies, although there were not enough students to establish specific themes regarding why. The two female students who reported that learning groups had an impact on their intent to study CS indicated a positive impact and expressed that they were influenced by their group members, specifically stating "I got to hear my group members' thoughts on the computer science major and I liked what I heard," and "I enjoy computer science more now that I realize how interesting it can be - a lot of people in the groups do really cool things with their computers," respectively. Of the eight male students who reported an impact, half indicated a positive impact, a quarter indicated a negative impact and a quarter indicated both positive and negative impacts. Examples of positive explanations from male students included "Yes, realized how much fun I could have in a career working with other people interested in comp. sci." and "Yes, it has given me an overview and I will try to minor." An example of a negative explanation from a male student was: "Yes because I realize how little I know about computer science." An example of an explanation that indicated both positive and negative reasons included "Yes, it both helped and hindered my progress. I would have worked harder on my own to know that material, but if I did not understand, the other members at least tried to explain to me the reason that the answers were what they were."

Comparison of learning groups with other instructional methods: Students were asked at the end of the semester how they thought learning groups compared to traditional learning methods such as lectures and textbooks. Students' answers were categorized into three types of responses: (1) learning groups are positive in comparison to traditional methods; (2) learning groups are negative in comparison to traditional methods; or (3) there is some variation (i.e., *either* learning groups are sometimes preferred and other methods are sometimes preferred, *or* learning groups are preferred only if certain conditions are met). While the number of female students who completed the end-of-semester-survey is small (15 female students total, and 7 freshman or sophomore level female students), it is noteworthy that there were more female students who indicated that learning groups were generally better than other more traditional methods, compared to those who indicated that other methods were generally better than learning groups. Male students tended slightly toward a preference for traditional learning methods. Figures 4.7 and 4.8 show the percentages of students who provided responses in each of the three categories. Figure 4.7 pertains to all students who provided a response and Figure 4.8 pertains to the freshman and sophomore level students only.

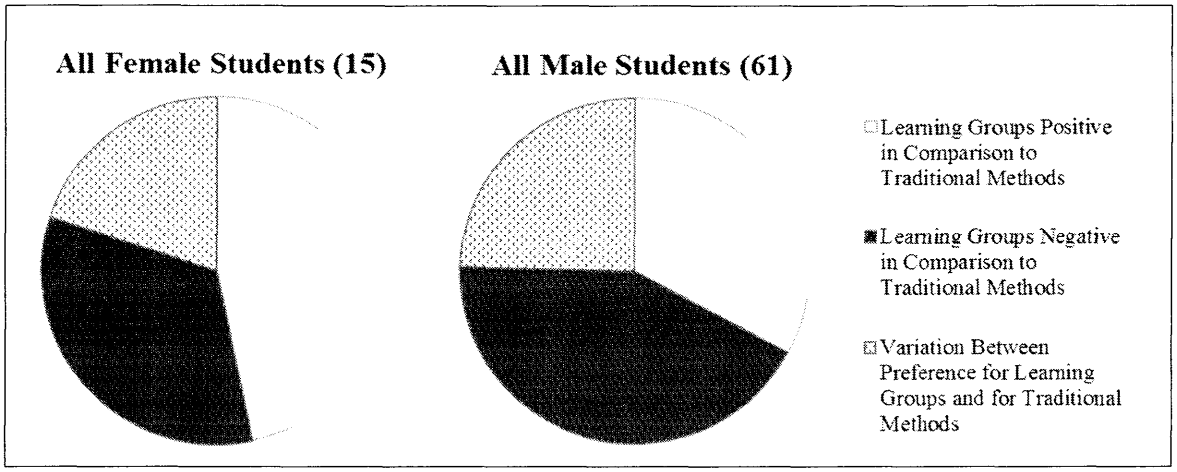

Figure 4.7. Students' reported perceptions of learning groups compared to more traditional learning methods.

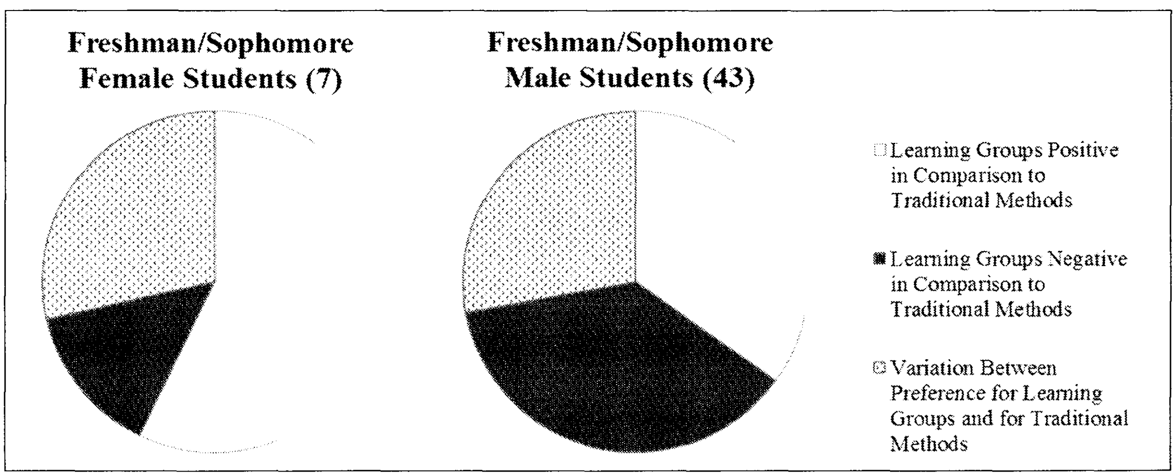

Figure 4.8. *Freshman/sophomore level* students' reported perceptions of learning groups compared to more traditional learning methods.

Many common themes for specific benefits of and problems with learning groups emerged in students' responses to this question. These themes are discussed in what follows.

Perceptions of learning groups (open-ended questions): Based on students' responses to other open-ended questions regarding formal learning groups, as well as students' responses when asked to provide any additional comments they have regarding their experiences with learning groups in CSCI 101, several themes emerged. There were specific benefits of or problems with learning groups, as well as conditions for learning groups to be successful, that were identified by students. While many students indicated that learning groups were generally positive (i.e., promoted learning, were engaging, were good, etc.) or generally negative (were bad, should not be used, etc.), specific categories also emerged. A list of specific response types that were given by multiple students (three or more), are as follows:

- Specific Benefits of Learning Groups:
    - Misconceptions (regarding content) can be avoided through discussion and/or explanations
    - Learning groups promote interactivity and active learning
    - The requirement of being responsible to the group promotes working harder
- Conditions for Learning from Formal Learning Groups:
    - Learning groups only work if sufficient lecture is incorporated as well
    - The success of a learning group depends on its members
- Specific Problems with Learning Groups:
    - Wasted time can be problematic (e.g., a group may not utilize time to do work)
    - Working with groups can cause misconceptions or poor understanding of content
    - The fact that one's grade depends on others is problematic
    - Less material can be covered (learning groups are less productive than other methods)
- Other: Learning groups are good for CS / CSCI 101 specifically

4.3.2 Related Interview and Focus Group Findings

Many details regarding students' perceptions of learning groups were presented when students explained aspects of CSCI 101 they liked and disliked (see section *4.2.2 Related Interview and Focus Group Findings*); many students who were interviewed or who participated in focus groups reported that they liked learning groups and/or disliked certain elements of learning groups. Interviewees were also asked what aspects of learning groups they liked and disliked most. Furthermore, students who participated in interviews or focus groups were given the opportunity to provide additional comments they wished to add regarding their experience with learning groups in CSCI 101. Finally, students who participated in individual interviews were asked if working in learning groups had any impact on their intent to pursue further studies in CS, and if so, to explain the impact.

Aspects of learning groups students liked and disliked most, and general comments regarding learning groups: When students reported that they liked learning groups when asked what aspects of CSCI 101 they liked, they included reasons such as motivation to work harder because their group depended on them, being comfortable asking questions in a small group setting, and meeting people. When students reported that they disliked learning groups when they were asked what aspects of CSCI 101 they disliked, they indicated reasons such as certain groups not fostering teaching and learning, needing to teach oneself the material since the group's contributions were insufficient, or needing additional lecture time on top of learning group work to make learning groups successful.

Some of the same themes came up when students were asked which aspects of learning groups they liked and disliked. Some additional items arose as well. For example, students found personalities of other students to have affected their experiences with groups:

> "Obviously you are going to have some people who are just really alpha personalities that need to be heard, but I mean that's with any group that you are going to have so I think it helps to learn to be able to deal with them too."
> (Interview: Female, Junior, Non-Major).

Additionally, the component of collaboration was indicated as beneficial:

> "Usually I don't talk in class at all so I think it helped to get my own ideas out and like, either clarify something or have the ideas gone over again."
> (Interview: Female, Junior, Non-Major)
>
> "It's kind of good just to have multiple perspectives, especially when you do something and then someone else does it and then you kind of get it, and they kind of get it, and you can put it together."
> (Interview: Male, Sophomore, CS Major)

Finally, one student commented that in his opinion learning groups are not appropriate for the college setting:

> "It'd probably be, not really as good at the collegiate level as it would for maybe like high school and middle school levels. Just probably more high school so they can be more mature and actually get work done in the group, but at the collegiate level I just don't really see it that much as being very successful."
> (Interview: Male, Sophomore, CS Major)

When students were asked in interviews and focus groups to provide additional information regarding learning groups, many students did not comment, but the students who did have a response included comments such as "it was really nice having the Google Docs. I've had a couple groups that didn't want to use them, and it makes it a lot harder to review, so that is one thing that definitely made it better … I've had a couple questions that I couldn't solve on my own over the weekend, and instead of waiting to get to class to ask the question, I just wrote a little note like 'Oh, I don't know how to do this, can someone else help me?' and then in four hours, they've written their answer up and I don't have to waste time in class asking the question," and "I was thinking maybe for people getting tired toward the end of the semester, maybe if you like stacked more of the … research book LGA stuff toward the beginning of the semester and then toward the end of the semester you did more uhh, interpersonal activities like in-class assignments, things like that, that might help, you know, work around that, as a possibility."

Impacts of learning groups on students' intent to study CS: Students had been asked via open-ended survey questions if learning groups had influenced their intent to pursue CS studies, and most students reported no impact. Students participating in interviews were also asked the same question. Similar results arose in the interviews as on the survey responses; most students indicated that learning groups did not have an impact on their interest in pursuing CS studies. However, a couple of students indicated some degree of influence from learning groups, such as seeing others who were interested in the field.

> "Maybe not, but it helped me look at it differently 'cause a lot of the people I worked with are really into the programming and everything so it helped me see it that way and I'm not big into programming so I didn't really think about how useful it would be but they would write programs for everything."
> (Interview: Female, Junior, Non-Major)
>
> "Somewhat, umm, there were some groups I was in, where there was the one who always had their computer open and just always like doing everything on the computer… . I don't know if it really changed my idea of what computing is, but it was just kind of fun to meet people who actually were like that." (Interview: Female, Junior, Non-Major)

4.4 Group Formations in Formal Learning Groups

Surveys, interviews, and focus groups were conducted to gather data related to students' experiences with specific learning groups. Findings from surveys, as well as additional details obtained through interviews and focus groups, are provided in the following sections.

4.4.1 Related Survey Results

To investigate students' reported perceptions of specific learning group formations, students were asked Likert-type survey questions about each group in which they participated. Additionally, students were asked at the end of the semester to rank the four groups they participated in from most to least effective, and from most to least inclusive, where inclusive indicates whether the student felt included in the learning and teaching process. From those data, a list of groups that appeared to offer positive experiences for female students was established and common group formations that appeared within that list of groups were identified. Moreover, through an open-ended survey question at the end of the semester, students were asked to describe why their most effective group was most effective. Similar questions were asked regarding the groups ranked as least effective, most inclusive, and least inclusive, as well.

Likert ratings of each learning group: Students were asked to rate eight different statements about their perceptions of each group they participated in, based on their level of agreement with each statement. As with other Likert-type questions on surveys used for this study, the response options were “Strongly Disagree,” “Disagree,” “Agree,” and “Strongly Agree.” The statements were all positive statements about the group, such as “In this group, I felt comfortable contributing,” and “I learned a great deal from this group.” The full list of statements is located in section *A.3 Learning Group Survey Questions*, in the Appendix. Results of the Likert responses were used in identifying groups that generally benefited female students. When a student agreed with all eight statements, for example, that was considered to be a positive contribution to the overall notion that the student was satisfied with the group.

Rankings of groups as most/least effective/ineffective: Students were asked to rank each of the four learning groups in which they participated from least to most effective, and from least to most inclusive. Results of these rankings were used along with the Likert response results to find groups that appeared to be positive for female students. Only groups that female students ranked as most or second-most effective, *and* ranked as most or second-most inclusive, were considered in the collection of groups that were most beneficial to female students.

Specific groups that seemed to be beneficial to female students: Of the 82 groups that worked together over the semester, 51 of them had at least one female student in them. Fourteen groups were identified as the key groups that showed the most positive outcomes. The subjective criteria used to identify those groups are outlined in section *3.3.3 Analysis of Learning Group Formations*. Note that 15 females completed surveys pertaining to the specific learning groups and 13 of them had groups that met the criteria.

Combinations of male and female students were reviewed to determine if there were any consistencies. Many of the groups (10 of the 14) consisted of at least two female students and four of the groups contained only one female student. Three of the groups had more females than males. Regarding students' levels of academic progress, there was typically heterogeneity in the level of academic progress of students; all but three groups had at least three different years (freshman, sophomore, etc.) represented. Next, students' majors and levels of progress in school were combined to estimate prior CS experience, and half of the groups contained no junior or senior level CS majors, whereas the other half of the groups had one or two. Combinations of students with different course performance levels (final course grades) were also considered. While all groups had at least two students who ultimately received a grade of "A" in the course, nearly half of the groups also had one student who ultimately received a grade of "D" or "F" or withdrew from the course. Two examples of group compositions that females reported positive perceptions of are outlined in Table 4.6.

Table 4.6. Sample group compositions: Compositions of two groups with which female student(s) had positive experiences.

Group: First Round (First of four groups during the semester)			
Student	**Gender**	**Academic Progress**	**Major Upon Entering CSCI 101**
1	Male	Sophomore	Non-Major
2	Male	Sophomore	CS Major
3	Female	Junior	CS Major
4	Male	Freshman	Non-Major
5	Female	Sophomore	Undeclared

Group: Third Round (third of four groups during the semester)			
Student	**Gender**	**Academic Progress**	**Major Upon Entering CSCI 101**
1	Female	Junior	Non-Major
2	Female	Sophomore	CS Major
3	Male	Senior	CS Major
4	Male	Senior	Non-Major
5	Female	Junior	CS Major

Properties of specific learning groups (open-ended questions): To obtain additional insights into properties of groups that were beneficial or detrimental to students, when students were asked to rank the learning groups they participated in based on effectiveness and inclusiveness, they were further asked the following questions:

- "Consider the most effective group. What was it about this group that made it effective?"
- "Consider the least effective group. What was it about this group that made it less effective?"
- "Consider the group in which you felt most included in the teaching and learning process. What was it about this group that made you feel included?"
- "Consider the group in which you felt least included in the teaching and learning process. What was it about this group that made you feel less included?"

Twelve female students and 59 male students provided responses to this set of questions. Students' responses were reviewed and categorized (see section *3.3 Data Analysis* for the analysis technique that was used to code open-ended survey responses). Each component of a student's response was generally categorized as one of the following:

- Group formation / combination of students
- Property or tendency of the group's interactions
- Trait possessed by one or more members of the group
- Action of one or more members of the group
- Feeling the student experienced in the group
- The timing of the group

Responses were also identified by specific characteristics. Results are summarized in Tables 4.7 through 4.11. Any student's response to a specific question may have incorporated multiple reasons, in which case multiple categories were associated with that student's response. Table 4.7 shows the number of male and female students who indicated specific group formations as reasons behind finding a group most effective, most inclusive, least effective, or least inclusive. Tables 4.8 through 4.11 display the results for all remaining general categories (i.e., excluding responses related to group formations).

Table 4.7. Reasons related to group formations that students reported for why specific groups were most/least effective/inclusive.

	Number of Students Who Selected a Particular Group Formation as the:			
Group formation	**Most Effective Group**	**Most Inclusive Group**	**Least Effective Group**	**Least Inclusive Group**
Many or all students were freshmen	1 Female *(Non-Freshman)*	1 Female *(Freshman)* 1 Male *(Non-Freshman)*	1 Male *(Non-Freshman)*	
Many or all students were upperclassmen	1 Male *(Upperclassman)*		1 Female *(Non-Upperclassman)*	1 Male *(Non-Upperclassman)*
There were varied levels of academic progress (e.g., freshmen & seniors)	1 Male			
There were varied *levels* of CS knowledge	1 Female			
There were varied *areas* of CS expertise / specialty		1 Male		

Table 4.8 displays the response types that were indicated by at least two students (either male or female) as reasons for groups being most effective or inclusive; similarly, Table 4.9 displays each of the response types that were given by at least two students for groups being least effective or inclusive.

As seen in Tables 4.8 and 4.9, some students indicated that a group's duration was a positive or negative factor (i.e., the time spent with the group was sufficient or insufficient, respectively). During the semester in which data were collected for this study, there were four rounds of learning groups; the groups were together for approximately four weeks, six weeks, three weeks, and two weeks, respectively. The discrepancy in group lengths was not intentional; rather, transitions between groups occurred at section breaks in instruction and the group lengths depended on the timing of those transitions. As a result of the discrepancy, however, it became evident that some students perceived groups that were together longer as more effective and/or inclusive.

Regarding the groups that students considered least effective or inclusive, some students explicitly indicated that their least effective and least inclusive groups were not necessarily ineffective or non-inclusive, respectively, but rather those groups were simply less effective or less inclusive (see Table 4.9).

Table 4.8. *Categories of responses* students provided when asked to explain why specific groups were their *most effective* and *most inclusive* groups. *

General Type of Response	**Specific Response Type ***
Property of Group	Group got to know each other
	Group *got along* well (no conflict) and personalities meshed
	Group *worked* well together
	Group discussed Learning Group Assignments / problems
	Group discussed Learning Group Assignments / problems *thoroughly*
	Group worked / met outside of class
	Group had similar ability levels or understanding
	Group joked around, had sense of humor, was fun
	Group talked / socialized
Personal Experience	I already knew someone in the group
	I felt comfortable participating
	I felt my contributions were needed / heard
	I didn't feel "stupid"
Action of Group Member(s)	Member(s) attended class
	Member(s) came prepared / did Learning Group Assignments
	Member(s) came prepared (specifically, posted to Google Docs)
	Member(s) contributed equally
	Member(s) focused on the group (e.g., not on laptop)
	Member(s) taught correctly / clearly
	Member(s) communicated well
	Member(s) listened to and valued input
	Member(s) were willing to answer questions / explain
Trait of Group Member(s)	Member(s) were enthusiastic
	Member(s) were knowledgeable
	Member(s) were motivated / invested or hard-working
	Member(s) were seniors and were helpful
	Member(s) were friendly / approachable
	Member(s) were easy going
Timing of Group	Group took place in beginning of semester
	Length of time in the group was sufficient

* Only response types that were given by two or more students are included in the table. Additionally, a student may have provided the same response regarding most effective and inclusive groups, and/or provided multiple responses to a given question.

Table 4.9. *Categories of responses* students provided when asked to explain why specific groups were their *least effective* and *least inclusive groups*. *

General Type of Response	Specific Response Type *
Property of Group	Group did not get to know each other
	Group *did not get along* well, personalities did not mesh
	Group did not discuss Learning Group Assignments/problems
	Group did not discuss Learning Group Assignments/problems *thoroughly enough*
	Group lacked similar interests
	Group did not talk / socialize much
Personal Experience	I felt uncomfortable asking questions or speaking up
	I felt I did not fit in
	I felt my contributions were not needed or heard
	I felt awkward and un-included in group conversations
	I felt I could not keep up with the group and material
Action of Group Member(s)	Member(s) were frequently absent
	Member(s) came unprepared / did not do LGA
	Member(s) came unprepared / did not do LGA (specifically, did the incorrect problems)
	Member(s) were unmotivated / un-invested or did not work hard
	Member(s) taught incorrectly
	Member(s) did not communicate well
	Member(s) only cared about their own grade
Trait of Group Member(s)	Member(s) were arrogant and thought they knew more than others
	Member(s) were condescending
	Member(s) were "too advanced"
Timing of Group	Group took place in end of semester
	Length of time in the group was insufficient
Other (Non-Reason)	Group was still OK (not ineffective, just less effective than other groups)
	Group was still OK (felt included, just less than in other groups)

* Only response types that were given by two or more students are included in the table. Additionally, a student may have provided the same response regarding least effective and inclusive groups, and/or provided multiple responses to a give question.

Tables 4.10 and 4.11 display the five most commonly given response types for each of the four questions, along with sample responses from the students (quotations).

Table 4.10. *Top five responses* given by females and by males for specific groups being *most effective* and being *most inclusive*. *

		Response Types	Num.	Sample Responses *
Responses Most Frequently Reported by *Female* Students	**Responses Regarding *Most Effective* Groups**	Group discussed LGAs/problems	3	"[We] shared everything we learned."
		Member(s) came prepared / did LGA	3	"Everyone came to class prepared to discuss the LGA"
		Group discussed LGAs/problems *thoroughly*	2	"We discussed the problems indepth and made sure everyone in the group fully understood every aspect."
		Member(s) were willing to answer questions / explain	2	"Whenever I had questions about one of the LGAs they would explain … until I understood."
		Group took place in beginning of semester	2	"It was the beginning of semester and everyone was doing their work and contributing."
	Responses Regarding *Most Inclusive* Groups	I felt comfortable participating	3	"I just started getting more comfortable with expressing my ideas with practice."
		Member(s) were willing to answer questions / explain	3	"Everyone seemed to want to help people who didn't understand."
		Group *worked* well together	2	"[We] worked very well together."
		Group had similar ability levels or understanding	2	"We were all at the same level of understanding."
		Group joked around, had sense of humor, was fun	2	" The guys were great and we always talked and had fun."
Responses Most Frequently Reported by *Male* Students	**Responses Regarding *Most Effective* Groups**	Group *worked* well together	9	"Teamwork is everything and this group worked so well together it was incredible."
		Member(s) came prepared / did LGA	8	"Everyone consistently did the assignments."
		Member(s) taught correctly / clearly	7	"Explained everything really well."
		Member(s) were knowledgeable	7	"Everyone knew a lot about computer science."
		Group took place in beginning of semester	7	"Beginning of the semester, everyone excited about school."
	Responses Regarding *Most Inclusive* Groups	Member(s) listened to and valued input	6	"Everyone (well, everyone except one) appeared to be paying attention to what I had to offer."
		Member(s) were friendly / approachable	6	"All the members of the group were easygoing and approachable."
		Group joked around, had sense of humor, was fun	5	"We joked around a lot after we got our work done."
		Group talked / socialized	5	"We talked about the homework and non-homework stuff."
		I already knew someone in the group	5	"I had two other people in my group whom I knew prior to the class."

* The number of occurrences of each response and the related sample quotations from students pertain to the given group (e.g., females) and the specific question (e.g., most inclusive) only.

Table 4.11. *Top five responses** given by females and by males for specific groups being *least effective* and being *least inclusive*. **

		Response Types	Num.	Sample Responses **
Most Responses Most Frequently Reported by *Female* Students	**Responses Regarding *Least Effective* Groups**	Group did not discuss LGAs/problems	4	"This group really didn't go over questions at all."
		Group took place in end of semester	3	"It was the end of the semester and the team was burnt out."
		Group did not discuss LGAs/problems *thoroughly enough*	2	"The group didn't focus too much on the small details of the problems."
	Responses Regarding *Least Inclusive* Groups	I felt my contributions were not needed or heard	2	"Group was more advanced in comp sci and so I felt like my contributions were not as worth while."
		Group did not discuss LGAs/problems *thoroughly enough*	2	"They were very focused on getting through the assignment as quickly as possible and not going into too much detail."
		Group was still OK (felt included, just less than in other groups)	2	"It wasn't that I didn't feel included, I just had to pick a group to be 'least.'"
Responses Most Frequently Reported by *Male* Students	**Responses Regarding *Least Effective* Groups**	Member(s) were unmotivated / un-invested or did not work hard	10	"No one cared."
		Group took place in end of semester	7	"At the end of the semester, focus dropped and the group didn't teach me as much as before."
		Group did not talk / socialize much	6	"Nobody talked to each other."
		Group was still OK (not ineffective, just less effective than other groups)	6	"Just that they were less effective, not [necessarily ineffective]."
		Length of time in the group was insufficient	5	"We weren't together long enough for us to do very much."
	Responses Regarding *Least Inclusive* Groups	Group did not talk / socialize much	7	"No one really socialized or got to know each other."
		Group did not discuss LGAs/problems	5	"Members did not want to discuss questions very much."
		Group did not get to know each other	5	"This one fell short because of the lack of group bonding."
		Length of time in the group was insufficient	5	"We didn't spend much time together so it was harder to create the proper connections with each other."
		I felt my contributions were not needed or heard	4	"Somehow I felt like everyone knew the answers and nothing I said could be of any help."

* Only the top three responses are reported for some questions (if only one student in the given group gave the response, the response was omitted from the table).

** The number of occurrences of each response and the related sample quotations from students pertain to the given group (e.g., females) and the specific question (e.g., least inclusive) only.

As shown in Table 4.10, many students also reported that their top ranked groups were most effective or inclusive because they took place in the beginning of the semester. Explanations included statements such as "Group members actually cared about the LGAs," "We were all more motivated to get the work done," and "The idea of LG's was fresh." Similarly, as shown in Table 4.11, many students reported that their least effective or inclusive groups were the ones that took place in the end of the semester; explanations included statements such as "All familiar with the subject so we were less motivated," "The team was burnt out," and "Focus dropped and the group didn't teach me as much as before." To investigate this phenomenon further, a link was made between each "most effective," "most inclusive," "least effective," and "least inclusive" ranking and the group identification number, and thus the learning group round number (e.g., first group). For example, if a student had ranked a particular group as the least effective group, it could be determined at which time during the semester the group took place. Compilation of the data showed that approximately half of all students (only 40% of female students) reported that their most effective group was the first group of the semester; similarly, about half of the students (just under half of female students) reported that their least effective group was the last group of the semester. Moreover, greater than 40% of students (but approximately 30% of female students) reported that the first group of the semester was both their least effective group and least inclusive group. The same was the case for last group of the semester being the least effective and least inclusive group.

Table 4.12 shows the number and percentage of students (out of the 15 female students and 63 male students who ranked their groups) who considered their first group to be their most effective and inclusive group, or considered their last group to be their least effective and inclusive group.

Table 4.12. Number of students who considered their first group to be the most effective and inclusive, or considered their last group to be the least effective and inclusive.

	First Group was Most Effective and Inclusive	**Last Group was Least Effective and Inclusive**
Females (15)	5 (33%)	4 (27%)
Males (63)	30 (48%)	28 (44%)
All Students (78)	35 (45%)	32 (41%)

Generally, students reported the same group when reporting their most effective group and most inclusive group, or their least effective group and least inclusive group. However, some students differentiated between the two. Table 4.13 displays the number of female students, male students, and all students combined, who put the groups in the same category.

Table 4.13. Number of students who reported the same group for most effective and most inclusive, or for least effective and least inclusive.

	Most Effective Group Same as Most Inclusive Group	**Least Effective Group Same as Least Inclusive Group**
Females (15)	8 (53%)	9 (60%)
Males (63)	48 (76%)	49 (78%)
All Students (78)	56 (72%)	58 (74%)

4.4.2 Related Interview and Focus Group Findings

In order to obtain additional information regarding students' ideas about learning group formations, several interview and focus group questions were posed. Focus group discussions targeted which learning group formations, or combinations of students, experience levels, gender, etc., were most and least effective and why. Moreover, the topic of combinations of male and female students, specifically, was discussed in interviews with female students; they were asked whether they felt more comfortable in learning groups with no other females or groups with other females, or whether it made no difference.

In the focus group discussions, several different themes were prevalent. The students' comments echoed some of the themes that emerged from the survey data. Students commented on age and level of CS experience of group members, as well as traits or tendencies of individual group members. Moreover, students provided explanations as to why certain combinations of students in learning groups were preferred or not.

Regarding age (level of academic progress) and experience with and knowledge of CS, the perceptions presented were varied, but many students preferred heterogeneity.

In one of the female focus groups, all but one female student commented that they preferred a mixture of CS knowledge or experience levels. Those students did not cite specific reasons as to why. The student who preferred more homogeneity stated:

> "My first group, … we all had very like, similar knowledge level, and I liked that one, 'cause those were the ones where we were actually willing to teach each other and we were wanting to learn, 'cause we all knew about the same amount of stuff to start with."
> (Focus Group: Female, Sophomore, Non-Major)

In the other female focus group, the idea of the specific benefits of freshmen and upperclassmen arose. The older female students mentioned benefits of having freshmen in a learning group such as added motivation (i.e., enthusiasm from younger group members), as well as additional learning that came from teaching the material more. The student's explanation regarding enhanced learning was as follows:

> "Well, freshmen being in my group also helped me because when they were struggling with something, I could explain it to them, and then it made me learn that material better, more. So having freshmen in my group definitely helped."
> (Focus Group: Female, Junior, Non-Major)

The freshman student in that same focus group mentioned that as a freshman, having upperclassmen or students with more CS experience in a learning group was beneficial in receiving explanations of concepts.

> "As a freshman it was nice to have people who understood it 'cause when I was just completely lost they could explain it, and I didn't feel like I was going to fail the class."
> (Focus Group: Female, Freshman, Undeclared Major)

Concern was also expressed by some students, however, that having students in a group that were too much more advanced was problematic in cases where the students were over critical or condescending. For example,

> *regarding a group with a senior CS major, a student stated*
> "There were days [*pause*] well, maybe I shouldn't even do my homework because he's gonna tell me I'm wrong, or he's going to critique everything I've said, and it was *really* intimidating to have to go and [*pause*] it was like the first week of school, and so it was extra intimidating. I think I

> would have enjoyed the class from the get-go better if had I had a different group."
> (Focus Group: Female, Junior, Non-Major)

The male focus groups each had one student who mentioned the importance of variance in CS experience (as well as variety in majors and years). Reasons cited included the variety of opinions given, as well as the following:

> "My most effective groups were those that were actually split between upperclassmen and freshmen. … So what would happen is we would come across a question, you know on the LGA, or, you know, during class, and sometimes the freshmen wouldn't know something and the upperclassmen would be able to thoroughly explain it, but then sometimes the upperclassmen would forget about the basics, you know, and the freshmen having to have read up on the basics to understand what's going on in class, would be able to, you know, explain those."
> (Focus Group: Male, Freshman, Undeclared Major)

Aside from the two individuals who reported benefits of heterogeneity in CS experience, the two male focus groups primarily emphasized issues of personality traits of individual members and group dynamics as influencing factors on experiences in learning groups. For example, the presence of students who are quiet is of concern because those students don't contribute as much and the presence of students who are condescending is problematic, whereas the presence of students who are hard-working or students who are friendly is beneficial to the group. The male students in one focus group also mentioned that taking time to have fun in the learning group and connecting on a personal level, and having similar personalities, were important.

Regarding combinations of female and male students within learning groups, the females who were interviewed were asked about their preferences. Furthermore, the topic arose in one of the two female focus groups in response to the question concerning which learning groups were most or least effective, and when the topic did not arise in the other female focus group, the moderator specifically asked "Did you feel more comfortable in groups with no other females, groups with other females, or was there no difference?"

Although many of the learning groups identified as providing positive experiences for female students contained at least two females (as summarized in section *4.4.1 Related Survey Results*), when female students were asked in an interview or focus group about their preferences regarding gender composition of groups, varying perspectives were provided. Some of the students did not have a comparison since all of the learning groups in which they participated had the same female / male composition.

Two of the female interviewees, as well as three of the female students who participated in focus groups, reported that they did not have a preference. Examples of such responses included the following:

> "I don't think having another girl in the group really made any difference, it's just the personality type and not the gender." (Interview: Female, Junior, Non-Major)
>
> "I would say there is no difference simply because I go to Mines and I'm really used to being in groups of [*pause*] that don't have other females in them."
> (Interview: Female, Senior, Non-Major)

Students (a total of three female students) who reported that having more than one female in the group was preferable, referenced feeling more comfortable working with other females and feeling ignored in a group where the rest of the members were male.

> "I probably felt a little more comfortable with at least one other girl in the group. … Probably just 'cause I feel more comfortable around them, I mean obviously it's Mines so you get used to talking to the guys and um, I've gotten a lot better with that because I'm a junior, but, like in high school I didn't really talk to guys that much so I mean I've gotten more used to it but there is still that underlying uncomfortable feeling you get but, I think at this point it's not as big of a deal, but maybe for freshmen it might be a little different." (Interview: Female, Junior, Non-Major)
>
> *In reference to a specific group a student called* "the perfect storm for the right group" *in a focus group discussion, a female student stated* "It was nice to have another girl 'cause I think sometimes there's this thing where if you're a girl in a group of four guys, you can sometimes get kinda overlooked. They're like, 'oh, she's

> just doing something over there, let's not worry about her.'" (Focus group: Female, Sophomore, Non-Major)

Two female students in one focus group and one female student in the other focus group reported that they preferred being the only female student in a learning group, referencing reasons such as getting along better with male students or the unwanted need for comparing oneself with other female students:

> "I worked better in groups with guys and I'm not quite sure why. … I find that I function better with a bunch of guys, and I think it's because I have over-blatantly jealous issues, so if other girls are there I'm always comparing myself to them and that's not as good, whereas if it's a group of guys, I'm more relaxed, I guess, so I work better in groups where I am the only girl."
> (Focus Group: Female, Junior, Non-Major)
>
> *Directly following the above comment in a focus group, another student commented* "I also work better with guys. I don't know, I just get along better with guys. There's so much less drama."
> (Focus Group: Female, Sophomore, Non-Major)

Generally, students' responses suggest that there may be some benefits to constructing learning groups in CSCI 101 with students of varying experience levels, and that if students with CS experience are in learning groups with inexperienced students, those groups are only positive if the experienced students are willing to be teachers and not criticize or belittle inexperienced students for their lack of experience. Moreover, findings suggest that having multiple female students in a formal learning group in CSCI 101 is not necessarily more beneficial for female students, and that different female students have different preferences for female / male combinations in learning groups.

CHAPTER 5 SUMMARY AND CONCLUSIONS

In this thesis, various instructional elements of the Introduction to Computer Science course (CSCI 101) at the Colorado School of Mines (CSM) were explored to identify instructional methods that can contribute to recruitment and retention of women in CS. CSM is an engineering university with approximately 4,000 students, 25% of whom are female. CSCI 101 was introduced at CSM in the Fall 2010 semester; participants of this study included students who were enrolled in CSCI 101 during the Spring 2011 semester.

5.1 Study Summary

CSCI 101 is an introductory CS course which provides an overview of the field of CS for students without prior CS or programming experience. The course introduces a broad variety of topics in CS through various instructional approaches (collaborative learning through formal learning groups, lecture, textbook-reading, and occasional use of electronic educational games) and presents basic computer programming concepts using the Python programming language. Formal learning groups represented a significant portion of students' learning experiences in CSCI 101. During the semester each student worked with four different groups of approximately five students each, collaborating with their teammates during every class meeting to teach one another new CS content and to solve problems.

This thesis explored the impacts of various instructional approaches implemented in CSCI 101 on students' interest in pursuing CS studies by examining how students ranked the different approaches in terms of how much students learned from and enjoyed the methods, and by assessing changes in students' intent to study CS after taking CSCI 101. Formal learning groups, specifically, were explored in more depth. Students' perceptions of formal learning groups, as well as impacts of learning groups on students' intent to pursue further CS studies were evaluated. Moreover, different group formations (i.e., combinations of female / male students, CS majors / non-majors, etc.) were investigated to explore whether certain formations were more or less beneficial to female students, and to identify properties of groups that students associate with more / less effective groups.

The investigation included the collection of self-reported data related to the following: (a) students' change in perception of computing in general and change in intent to pursue CS studies after taking CSCI 101; (b) students' opinions about the various instructional methods utilized in the course; (c) students' perception of learning groups in CSCI 101; (d) learning groups' impact on students' intent to study CS; and (e) students' perceptions of the specific learning groups they participated in.

A mixed-research approach was taken for the study; that is, both quantitative and qualitative data were collected and analyzed. Data collection entailed surveys, as well as one-on-one interviews and focus groups. All students enrolled in CSCI 101 during the Spring 2011 semester (20 female students and 82 male students) were invited, but were not required, to participate in the study. Fifteen female students and 61 male students (76 students total) took all of the surveys. Two female students and two male students who were enrolled in the course ultimately withdrew from the course and were unavailable for participation at the end of the semester. A randomly selected subset of students were invited to participate in an interview or focus group; four females and four males participated in interviews, and there were two female focus groups (four students each) and two male focus groups (three students each). Survey, interview, and focus group questions were developed to answer the research questions associated with this study. Surveys were conducted via online website applications; individual interviews and focus groups were conducted by the researcher.

5.2 Study Limitations

Limitations to this study include: potential sources of bias, small number of participants, and lack of validated survey instruments. The limitations and their implications are described next.

The first limitation of the study was that some issues represented potential for bias in the results, particularly in regards to qualitative findings. One concern was that most data collected were acquired via self-reporting. With self-reporting, there are potential risks that participants may not answer questions realistically due to fear of how their responses will be interpreted or used, intent to answer questions as they perceive the researchers wish them to answer the questions, etc. A source of potential bias in this study in particular was that the researcher / interviewer was a co-instructor of CSCI 101, the course under study. The teacher-student relationship may have had unknown influences on students' responses. To alleviate some of these risks, several measures were taken. For example, participants' responses in surveys, interviews, and focus groups did not influence students' grades and they were informed as such; despite being a co-instructor for the course the researcher did not have control over the students' grades. Additionally, during interviews and focus groups, the interviewer showed interest in and encouraged all types of responses regardless of their nature.

Some factors surrounding students' perceptions of learning groups and other instructional methods used in CSCI 101 were not explored and as a result, some influences may not have been noticed. For example, students were not asked about their perception of the content presented within the various learning group assignments, but content difficulty and/or appeal may have influenced students' perceptions of learning groups.

Since participation was voluntary, some students' perspectives may have been missed, or the results may have been skewed. The response rate on surveys was approximately 75%, so the selection bias should not be substantial.

Bias can also arise in individual participants' responses if there is confusion over the meaning of questions (i.e., what the researcher is actually asking). To minimize that form of bias in this study, survey questions were pilot tested before use. Pilot testing occurred in Fall 2010 and necessary changes were made to questions prior to the beginning of the Spring 2011 data collection.

Finally, certain sources of bias are possible in qualitative inquiry, such as researcher bias. To avoid researcher bias in this study, strategies such as triangulation and considering aspects of findings that oppose favored outcomes, were employed. Triangulation techniques that were used included having two individuals independently code qualitative responses and using multiple forms of data collection. Care was taken during analysis to consider and report various explanations including those that countered the idea that instructional methods used in CSCI 101 lead to recruitment and retention of women in CS.

A second limitation of this study was that the population size was small. Due to the low number of female participants (20 female students), quantitative data did not provide statistical significance and analysis thereof was limited to descriptive statistics. To lessen the concerns regarding the small participant base in this study, qualitative data were also collected and analyzed to provide additional insights into results.

Another limitation of this investigation was that although the survey instruments were pilot tested, they were not validated. Since the data were not derived from validated instruments, there may be unknown sources of bias in the data. Furthermore, due to the lack of validated survey instruments and the small number of participants, the study results are subsequently not directly extendible to other populations; rather, they pertain only to the group that was studied (students taking CSCI 101 at CSM). Additional research with validated instruments and larger participant populations is required to obtain results that are more applicable to other students and universities.

5.3 Conclusions and Future Direction of Related Research

The findings from the collected data were presented in this thesis and are summarized here. Recommendations for related research efforts based on findings are also included.

5.3.1 Recruitment and Retention Efforts

One of the primary objectives of this research was to determine if and what types of potential for recruiting and retaining women in CS exist within instructional techniques used in an introductory CS course. The course that was explored was CSCI 101 at CSM. Changes in students' perceptions of computing in general, as well as intent to major in CS or otherwise pursue CS studies, were measured to provide a basis for understanding whether recruitment and retention had been successful.

There was insufficient data to determine whether students' perceptions of computing had changed positively or negatively after taking CSCI 101. Regarding students' intent to pursue additional CS studies, there were no significant changes in students' interest in majoring in CS. Of the students who came into the course as CS majors, one male student indicated at the end of the semester that he was no longer interested in majoring in CS. The remainder of the CS majors retained an interest in the major, indicating that retention of students in the major was primarily positive. Of the students who came into the course undeclared or with non-CS majors (roughly three quarters of the female students who took the surveys and one half of the male students who took the surveys), two male students lost interest in majoring in CS, whereas one female and two male students gained an interest in majoring in CS. While there was one female student who decided after taking CSCI 101 that she was then interested in pursuing a CS major, overall these results indicate that recruitment into the major was not necessarily successful.

5.3.2 Impacts of Various Instructional Methods Used in CSCI 101

The first research question posed in this thesis was *Which instructional methods, including formal learning groups and traditional instructional techniques, do students rank as most effective in promoting their interest in continuing Computer Science studies?*

To explore the instructional methods, students were asked to rank five different learning constructs used in CSCI 101 based on how much the students learned from and enjoyed each of them. The five learning modalities were participating in formal learning groups, reading a textbook, observing lecture, programming in Python, and playing/watching electronic educational games. While the different learning methods were not used for the same amount of time during class and the different activities were not necessarily used to learn the same material, students' perceptions of how much they learned from and enjoyed the various methods may provide insight into which types of instructional methods promote students' interest in participating in CSCI 101, and in turn, promote their interest in studying CS. Many female and male students reported the textbook as the instructional method from which they learned the most. Use of the textbook was required for learning in CSCI 101 since students read the textbook to prepare for learning group discussions, which may suggest that requiring the use of a textbook can increase the level of benefit students perceive textbooks offer. Learning groups were the construct that most female students reported enjoying most. Furthermore, many female students reported learning groups as the method from which they learned the most (an equal number of female students reported textbook and learning groups). Reported benefits of learning groups are discussed later in this section in the context of research on the impacts of learning groups in particular. Finally, despite the low number of male students who reported programming in Python as the method they learned the most from, more male students reported programming as the one they enjoyed most than any other method. There may be a correlation between this outcome and the fact that many of the male students in the study had prior programming experience; those students may not have learned a great deal from programming in Python given their experience with other programming languages, but they enjoyed it nonetheless.

Interviews and focus groups revealed additional details regarding the different learning constructs and students' positive and negative attitudes toward those constructs. The most common reasons for enjoying learning groups were that being responsible to a group of people provided additional motivation to work hard, that learning groups allowed students to ask questions because of the small group setting (as contrasted with asking questions in front of a large class), and that learning groups gave students the opportunity to meet people. On the other hand, some students identified learning groups as an aspect of the course they did not like, stating reasons such as not being able to go into sufficient depth into topics and having difficulty with certain groups (e.g., some groups did not teach sufficiently and students felt they needed to learn everything on their own as a result). When students discussed reasons that they enjoyed programming in Python, they cited explanations such as ease of use of the language itself. The students who indicated that Python was easy had prior experience with other programming languages and were comparing Python to those languages. Other students mentioned that the Python programming was too advanced and required more guidance and teaching than had been provided in class. These findings suggest that Python is an appropriate programming language for this course since it is more comfortable for students than other languages, but that sufficient instruction is essential. Although many of the students who participated in interviews and focus groups indicated that learning groups and Python programming were aspects of CSCI 101 that they *liked or disliked*, there were no instructional methods used in CSCI 101 that emerged as causes for *changed levels of interest in CS in general or in studying CS.* In fact, many students referenced the wide scope of the topics covered in the course as having the most influence on their interest in CS. Students appeared to appreciate learning about a variety of topics beyond programming alone and receiving an overview of the subject, which parallels the findings of Alvarado & Dodds (2010) who found the use of a broad introductory course to be a promising practice in recruitment and retention of women in CS.

In summary, this study found that many students in CSCI 101 felt they learned most from reading the textbook and many students reported enjoying programming in Python the most (although the small number of female students reported learning from and enjoying learning groups as well). Since most students who took CSCI 101had no change in their interest in studying CS, an assessment of which instructional methods they rank as most effective in promoting their interest in CS studies was not obtainable.

5.3.3 Impacts of Formal Learning Groups

The second research question of the study was *What impact do learning groups have on female students in terms of their reported perception of, excitement about, and intent to major in, Computer Science?*

A more in-depth study of formal learning groups was conducted in which students reported on their perceptions of learning groups in CSCI 101, how they compared learning groups to traditional learning methods, and whether / why learning groups had an impact on their intent to study CS. The results showed that many female students who took the course reported that they learned from and enjoyed learning from formal learning groups. For example, when students were asked to compare learning groups with traditional learning methods, there were more female students who indicated that learning groups were positive compared to traditional methods than those who indicated that learning groups were negative compared to traditional methods. Overall (i.e., considering all students), however, more students indicated a preference for traditional methods. As stated previously, many female students ranked learning groups higher than other instructional methods used in CSCI 101 in terms of enjoyment and learning. Some of the specific benefits of formal learning groups that female students identified (either in survey responses or in interviews or focus groups) were the added comfort in participating due to the small group size (i.e., not needing to speak before the whole class) and the additional interactivity with others that learning groups provided. These outcomes indicate that the use of learning groups has the potential to meet the recommendation to offer introductory CS courses with inclusive pedagogies that strengthen women's confidence (NCWIT 2011).

Although there were different benefits that students tended to associate with learning groups, certain problems with learning groups emerged as well. Many students indicated that time was wasted during some of their groups' discussion time, that working with groups often caused misconceptions or poor understanding of content, that more lecture time would be needed for the learning groups to be an effective construct, or that the quality of the learning group experience varied greatly depending on the group (e.g., members' behaviors). Although learning group discussions in CSCI 101 were monitored and instructors provided clarifications regarding content misconceptions as needed, these findings indicate that a more rigorous approach to observing and influencing learning group interactions are needed for learning groups to be most successful. For example, instructors could observe groups and assign grades for students' participation during the observation, and/or grade students' learning group assignments (i.e., content students are teaching their group mates) based on correctness.

To summarize the impacts learning groups had on female students and their perceptions of and intent to major in CS, there was no indication that formal learning groups in CSCI 101 had a direct impact on female students' (or male students') interest in CS or pursuing CS studies, but many students (particularly underclass students, who are good candidates for CS recruitment) enjoyed learning groups and there were aspects of the groups that students reported as beneficial in their motivation to participate. Results indicating that female students enjoyed formal learning groups in CSCI 101 suggest that incorporating learning groups into an introductory CS course may have the potential to promote female students' interest in CS. Additional research, particularly with a larger female population, would be valuable. Furthermore, there are some aspects of learning groups that students in CSCI 101 perceived as negative; additional investigations into mitigating those problems would also be beneficial.

5.3.4 Learning Group Formations and Properties of Learning Groups

The final research question examined in this thesis was *What impact do specific learning group formations have on female students' reported learning experiences in formal learning groups within an introductory Computer Science course?*

A further exploration of formal learning groups was conducted regarding specific group formations and the impacts that different types of groups had on female students' experiences in learning groups within CSCI 101. There were not any specific combinations of students that were identified as being decidedly more or less beneficial to female students' perceptions of groups. However, many general properties of groups that provided either positive or negative experiences for students were identified.

Specific groups of students were identified as being generally positive for one or more female students based on their perceptions of those groups. The compositions of those groups were reviewed and compared to explore whether there were any trends in combinations of students that were common among the groups. Moreover, feedback that was obtained from students regarding positive and negative properties of specific groups (data obtained from open-ended survey questions, interviews, and focus groups) provided a great deal of insight into students' perspectives.

Combinations of male and female students in groups were explored. Many of the groups that were identified as being positive for female students had at least two females in the group. These results may indicate that female students in CSCI 101 typically preferred groups with more than one female; however, interview and focus group comments showed that female students had varying preferences. Specifically, many of the female students who were asked about their preferences of female / male combinations in groups stated that they did not have a preference, some of whom indicated specifically that they had become accustomed to working in male-dominated groups at CSM. Several of the female students reported that having another female in a learning group was better, referencing feeling more comfortable working with other females or feeling ignored in a group with no other females; these responses are commensurate with research that shows that there can be negative impacts on female students in groups containing one female and the rest male students (Webb 1989). Opposing responses were also given; some female students reported a preference for being the only female in a learning group, indicating that they got along better with males or that they did not have to compare themselves to other females when there were no other females in the group. Additional inquiry into the benefits of learning groups with different combinations of male and female students would be beneficial. A study that incorporated controlled comparisons may be especially useful.

There was a spread in students' preferences in terms of homogeneity vs. heterogeneity in levels of CS experience and/or ability levels within groups, although there was a slight tendency toward a preference for heterogeneity. Students' comments suggest that there may be advantages in constructing learning groups in CSCI 101 with varying experience levels, but that groups with extreme variations are only beneficial if the highly experienced students are not condescending to the less experienced students, but rather take on the role of teacher in the group. The dynamics of the learning groups that took place during this study were likely different than typical dynamics of learning groups in an introductory CS course due to the uncharacteristically large number of experienced CS majors enrolled in the course. As a result, a similar study *after* upperclass CS students are no longer participating in the course is necessary to gain more relevant conclusions.

When students were given the opportunity on a survey to provide details regarding why their best groups were more effective or more inclusive, and why their worst groups were less effective or less inclusive, answers ranged from tendencies of the groups as a whole, to actions or traits of one or more members, to personal feelings that the groups elicited. While the properties that students described were not necessarily properties that can be controlled by placing specific combinations of students together in groups, students' feedback may be applied to improving learning groups. The characteristics of effective groups that appeared to be most important to students were preparedness (group members coming into group discussions prepared to teach) and motivation and willingness to contribute to the learning group discussions (especially providing *thorough* explanations). As mentioned in section *5.3.3 Impacts of Formal Learning Groups*, incorporating additional measures into course instruction that promote increased accountability within learning groups may be beneficial; such measures could be taken to increase students' preparedness and participation in groups.

Many students also indicated that their most effective group was most effective because it took place at the beginning of the semester, and/or that their least effective group was least effective because it took place at the end of the semester. In fact, approximately half of the students who were surveyed ranked their first group as their most effective group and about half of the students (not necessarily the same students) ranked their last group as their least effective group. The primary explanation that students gave was the presence or lack of motivation in the beginning or end of the semester, respectively.

For students to feel included in the teaching and learning process within groups, it was important for the groups to socialize and/or have fun together, to have members who were friendly, and to have members who listened to and valued other students' input. Some students also reported that they felt more included when they knew someone in the group beforehand. Some additional properties of groups that were important to female students were feeling comfortable participating, feeling that their contributions were valued, and having members in the group who were willing to answer their questions. To promote socialization and fun, instructors could include a small amount of time for socialization and/or encourage students to get to know one another, especially when each group is initially formed. To promote other inclusive behaviors in group members and help students to feel that their input is valued, it may be beneficial for instructors to utilize feedback from students regarding individual group members' performance to encourage positive behaviors and discourage negative ones. There may be particular advantages to placing students of particular personality types in groups to foster inclusion. Based on findings of this study, additional research regarding combinations of personality types within learning groups in CSCI 101 may be productive.

The ultimate findings of the exploration of learning group formations indicated that there were not any specific formations that contributed to female students' positive or negative perceptions of learning groups, but that certain characteristics of groups such as motivation, preparedness, and approachability, were needed for fostering positive group environments.

5.3.5 Concluding Remarks

Findings from this research indicate that there may be potential for aspects of CSCI 101 at CSM, including formal learning groups, to be beneficial in recruiting and retaining women in CS studies. There was no direct link between students' experiences with formal learning groups or other instructional methods and female students' intent to pursue CS studies. However, there were aspects of CSCI 101 that students learned from and enjoyed, indicating the potential for promoting students' interest in studying CS. Moreover, this study identified some elements of various instructional methods within the course that students did not enjoy, which provided insights into ways to improve the course.

Additional investigations are required in several areas, particularly the use of formal learning groups in introductory CS courses. Repetition of a similar study after upperclass CS students are no longer participating in the course would be useful in obtaining results that pertain to a typical population in an introductory CS course. Furthermore, studies with higher numbers of female students (e.g., studies that span multiple semesters) and validated instruments are needed to gather quantitative data that can provide statistical significance. Studies in different university settings, such as liberal arts schools, schools with large computer science departments, etc., may be of interest as well.

Currently CSM intends to continue the use of formal learning groups in CSCI 101, giving the opportunity for additional data collection regarding students' perceptions of learning groups. Moreover, while it is beyond the scope of this thesis work, female students may be followed through their studies to identify any changes in their enrollment in the CS program, for the purpose of measuring retention. Any additional research at

CSM or elsewhere which further investigates formal learning groups in introductory CS courses and their potential to promote recruitment and retention of women in CS, will strengthen the findings of this thesis work.

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APPENDIX A SURVEY QUESTIONS

A.1 Beginning Survey Questions

The following is the set of questions asked only at the beginning of the CSCI 101 semester. *Italicized questions were present on the survey but were not used for the purpose of this research.*

1) Enter your full name (First Last): ______________________

2) Enter your age (in years): ______________________

3) Enter your gender (select the one that applies to you):
   ____Female ____Male

4) *Are you Hispanic or Latino?*
   ____Yes ____No

5) *Enter your Ethnicity (place a check next to the one that applies to you):*
   ____ American Indian or Alaska Native
   ____ Asian
   ____ Black or African American
   ____ Native Hawaiian or Other Pacific Islander
   ____ White
   ____ Other

6) *Enter the semester and year you started attending Colorado School of Mines.*
   Semester (Fall/Spring): __________
   Year: __________

7) *If you transferred from another institution, indicate the number of semesters you completed at that institution:* ________________

NOTE: Data from the registrar, rather than responses to questions 6 and 7 above, were used to determine students' level of academic progress (freshman, sophomore, junior, or senior).

8) *What is the **primary** reason you are taking Introduction to Computer Science?*
   ____ Catalog-change requirement
   ____ Automatic placement by Registrar
   ____ Interest in computing
   ____ Other: Reason ________________________________

9) List your declared majors and/or minors. For each, enter the date you declared (approximate date is sufficient). Note: if you have not yet declared a major, write "Undeclared" for the first major.

   Major ____________________________ Date Declared ________________________
   Major ____________________________ Date Declared ________________________
   Minor ____________________________ Date Declared ________________________
   Minor ____________________________ Date Declared ________________________

10) List three things having to do with computers that you feel you are very good at, perhaps so much so to be called an "expert".

11) From the following words/phrases, check the four that you feel have the strongest connection to the term "computer science".

A.2 Pre / Post Survey Questions

The following is the set of questions asked both at the beginning and the end of the CSCI 101 semester, for the purposes of assessing changes in students' perceptions after taking the course. *Italicized questions were present on the survey but were not used for the purpose of this research.*

1) Are you considering further studies in CS in any of the categories below? If so, check all categories you are considering. If not, check "None".
   ____ Major
   ____ Minor or ASI (Area of Special Interest)
   ____ Taking additional CS courses without pursuing a CS major/minor/ASI
   ____ None

For the following questions, rate each statement based on your level of agreement with the statement.

	Strongly Disagree	Disagree	Agree	Strongly Agree
2) Computing is fun.				
3) Computer programming is difficult.				
4) Computing-related jobs are boring.				
5) I am interested in a computing-related career.				
6) I am interested in how computer hardware works.				
7) I am interested in learning how to design and/or develop computer software.				
8) Computing is useful in everyday life.				
9) Learning computing skills will help me during college.				
10) Developing computing skills will help me in my career.				
11) <u>Ask at beginning of semester</u>: Introduction to Computer Science (CSCI 101) will be boring. <u>Ask at end of semester</u>: Introduction to Computer Science (CSCI 101) was boring.				
12) <u>Ask at beginning of semester</u>: This class (CSCI 101) is intimidating. <u>Ask at end of semester</u>: This class (CSCI 101) was more difficult than I anticipated.				

	Strongly Disagree	Disagree	Agree	Strongly Agree
13) Ask at beginning of semester: Programming in Python will be fun. Ask at end of semester: Programming in Python was fun.				
14) Ask at beginning of semester: In formal learning groups in CSCI 101, I will do more "teaching" of my fellow students than learning from them. Ask at end of the semester: In formal learning groups in CSCI 101, I did more "teaching" of my fellow students than learning from them.				
15) Ask at beginning of semester: I will have fun working in formal learning groups in CSCI 101. Ask at end of semester: I had fun working in formal learning groups in CSCI 101.				

*16) List five things that come to mind when you hear the term "**computing**".*

17) How many hours (approximately) do you spend on the computer at home or school each day? _____ Hours
Of those hours, how many are spent doing the following activities:

- *Doing school/course work? _____ Hours*
- *Interacting with friends (email, IM, chat, using social networking sites)? _____ Hours*
- *Using multimedia apps for fun (playing games, watching videos, listening to music, etc.)? _____ Hours*
- *Learning about a topic of interest (researching a topic online, tutorials, Wikipedia, etc.)? _____ Hours*
- *Programming (**not coursework-related**)? _____ Hours*
- *Doing other activities? _____ Hours*
  What kind of other activities? ________________________________

A.3 Learning Group Survey Questions

The following is the set of questions that each students was asked for each learning group in which s/he participated.

Consider **Group X** (<Names of group members >)
For each statement, rate your level of agreement with the statement for this group.

	Strongly Disagree	Disagree	Agree	Strongly Agree
1) This group promoted creativity.				
2) I had fun with this group.				
3) This group was conflict-free.				
4) This group motivated me.				
5) This group made me feel confident in my abilities.				
6) In this group, I felt comfortable contributing.				
7) I learned a great deal from this group.				
8) I got excited about computer science with this group.				

9) Please provide any additional comments you have regarding your experiences with this learning group.

A.4 End Survey Questions

The following is the set of questions asked only at the end of the CSCI 101 semester. *Italicized questions were present on the survey but were not used for the purpose of this research.*

1) Rank the following in CSCI 101 in terms of how much you learned from each of them, where 1 is the one from which you learned the most and 5 is the one from which you learned the least:

    _____ Reading the Textbook
    _____ Participating in Learning Groups
    _____ Observing Lecture
    _____ Programming in Python
    _____ Playing/Watching Computer Games

2) Rank the following in CSCI 101 in terms of how much you enjoyed learning from each of them, where 1 is the one you enjoyed the most and 5 is the one you enjoyed the least:

    _____ Reading the Textbook
    _____ Participating in Learning Groups
    _____ Observing Lecture
    _____ Programming in Python
    _____ Playing/Watching Computer Games

3) *[Likert question (with "Strongly Disagree," "Disagree," "Agree," and "Strongly Agree" response options)]: Computer Science is an asocial field.*

4) *Regarding the previous statement [CS is an asocial field] has this perception changed since taking CSCI 101?*

5) *[Regarding the previous statement] If your perception has changed, what caused that change?*

6) Did working in learning groups have any impact on your intent to pursue further studies in Computer Science?

7) How do you think learning groups compare to traditional learning methods (e.g. lecture and textbook)?

8) Please provide any additional comments you have regarding your experience with learning groups in this course.

Consider your groups:

Group A (Dates)	**Group B** (Dates)	**Group C** (Dates)	**Group D** (Dates)
<Names of group members >	<Names of group members >	<Names of group members >	<Names of group members >

9) Rate the groups from most effective to least effective (write each group number in the blank).

Most Effective **Least** Effective

Group ____	Group ____	Group ____	Group ____

10) Consider the most effective group. What was it about this group that made it effective?

11) Consider the least effective group. What was it about this group that made it less effective?

12) Rate the groups from most inclusive to least inclusive, where inclusive means you felt included in the group and felt comfortable teaching and asking questions of your group members.

Most Inclusive **Least** Inclusive

Group ____	Group ____	Group ____	Group ____

13) Consider the group in which you felt most included in the teaching and learning process. What was it about this group that made you feel included?

14) Consider the group in which you felt least included in the teaching and learning process. What was it about this group that made you feel less included?

APPENDIX B STUDENTS' CHANGED PERCEPTIONS OF COMPUTING

This Appendix includes findings that are supplemental to the findings of the study outlined in this thesis, but that are not influential on the conclusions.

Table B-1. Changes in Likert responses after taking CSCI 101 (related to students' perceptions of computing). *

	Statements related to students' perceptions of the *usefulness* of computing.								
	Computing is useful in everyday life.			Learning computing skills will help me during college.			Developing computing skills will help me in my career.		
	Pos. Change	Zero Change	Neg. Change	Pos. Change	Zero Change	Neg. Change	Pos. Change	Zero Change	Neg. Change
Females	33%	53%	13%	40%	33%	27%	20%	67%	13%
Males	10%	75%	15%	18%	70%	11%	7%	82%	11%
All	14%	71%	14%	22%	63%	14%	9%	79%	12%

	Statements related to students' *interest* in computing.								
	I am interested in a computing-related career.			I am interested in how computer hardware works.			I am interested in learning how to design and/or develop computer software.		
	Pos. Change	Zero Change	Neg. Change	Pos. Change	Zero Change	Neg. Change	Pos. Change	Zero Change	Neg. Change
Females	27%	53%	20%	20%	40%	40%	13%	67%	20%
Males	15%	67%	18%	20%	54%	26%	15%	67%	18%
All	17%	64%	18%	20%	51%	29%	14%	67%	18%

	Statements related to students' other perceptions of computing.								
	Computing is fun.			Computing-related jobs are boring.			Computer programming is difficult.		
	Pos. Change	Zero Change	Neg. Change	Pos. Change	Zero Change	Neg. Change	Pos. Change	Zero Change	Neg. Change
Females	27%	67%	7%	7%	60%	33%	27%	33%	40%
Males	20%	61%	20%	21%	62%	16%	21%	56%	23%
All	21%	62%	17%	18%	62%	20%	22%	51%	26%

* All Likert-type questions at the beginning and end of the CSCI 101 semester had "Strongly Disagree," "Disagree," "Agree," and "Strongly Agree" as response options.

Table B-2. Changes in Likert responses after taking CSCI 101 (related to students' perceptions of the course).*

Statement:	Programming in Python will be / was fun.			CSCI 101 will be / was boring.		
	Positive Change	Zero Change	Negative Change	Positive Change	Zero Change	Negative Change
Females	27%	53%	20%	20%	47%	33%
Males	33%	48%	20%	16%	57%	26%
All	32%	49%	20%	17%	55%	28%

* All Likert-type questions at the beginning and end of the CSCI 101 semester had "Strongly Disagree," "Disagree," "Agree," and "Strongly Agree" as response options.

Table B-3. Students' perception at the end of the semester regarding CSCI 101's difficulty level, according to a four-point Likert scale.

Statement:	This course (CSCI 101) was more difficult than I anticipated	
	Positive Response (Strongly Disagree or Disagree)	Negative Response (Strongly Agree or Agree)
Females	9 (60%)	6 (40%)
Males	34 (54%)	29 (46%)
All	43 (55%)	35 (45%)

APPENDIX C IRB EXEMPTION LETTER

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

Wendy J. Harrison, Ph.D.
Associate Provost
Professor of Geology and Geological Engineering

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Golden, CO 80401-1887
Office: 303-273-3821
Fax: 303-273-3040

February 23, 2011

Dr. Irene Polycarpou
Colorado School of Mines
Department of Mathematical and Computer Sciences
Golden, CO 80401

Dear Dr. Polycarpou:

In consultation with Associate Legal Counsel Esther Henry, I am pleased to grant your request for an Institutional Review Board exemption for the human subjects research you propose to conduct related to the project entitled, "Assessments of Introduction to Computer Science (CSCI 101)." The details of your work are described in hard copy and electronic communications in February 2011 and have been retained in our files in Academic Affairs.

Your project involves the collection or study of future data. Your exemption is granted under the following provision(s) of 45 C.F.R. 46.101(b):

> ***(1)*** ***Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.***
>
> ***(2)*** ***Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.***

Please adhere to the measures you cite in your proposal to safeguard the privacy of the subjects and to ensure that no risk is posed to them as a result of participation in your research.

If, during the course of your study, there is a need to make significant changes to the research protocols, you should advise Esther Henry and me so that we may consider the necessity of amending any part of this exemption approval.

CSM requires project investigators to complete an on-line training course pertaining to research practices involving human subjects. The course must be completed by all investigators, co-investigators and student researchers. Our records show that you have already completed the course. However, Keith Hellman and Julia Krause will be required to complete it as well.

Here are instructions on how to self-enroll in the course:
http://www.citiprogram.org/citidocuments/ADMIN/Steps%20to%20register%20with%20CITI.ppt

Here is the actual course:
http://www.citiprogram.org/

You should select the module "Data or Specimens Only Research - Basic/Refresher, Basic Course". The course takes about 8 hours to complete and it is designed to allow you to access, save, and continue on multiple occasions so that you do not need to take the whole course in one unit. Please print the certification of completion page and provide a copy to Jennifer Parrilli, Academic Affairs, for our files. If you have questions about the website contact either Esther Henry or myself for assistance.

Sincerely,

Wendy Harrison

Wendy Harrison
Associate Provost

WJH/jp

cc: File
John M. Poate Vice President for Research and Technology Transfer
Esther Henry, Associate Counsel
DH
All co-investigators