Board 60: Work in Progress: Student Perspectives of Collaborative Learning Techniques (CoLT) in Introductory Computing Classes

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Lisa Cullington, Ph.D. is an educational researcher with expertise in academic program development, learning outcomes, and educational assessment best practices. She focuses on building and evaluating academic programs that promote inclusive excellence for all learners. Currently, Dr. Cullington serves as the Associate Provost of Academic Programs at Sacred Heart University. Previously, she was the Founding Co-Chair of the Honors Program at SUNY Farmingdale and Associate Director of the Research Aligned Mentorship (RAM) Program where she designed, implemented, and evaluated academic programs to engage students from historically minoritized communities in undergraduate research opportunities. She has served as a principal investigator and educational researcher on number grant initiatives, including grants from the National Science Foundation and the United States Department of Education.

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Mary V. Villani is an Associate Professor at Farmingdale State College (FSC) in the Computer Systems Department. She holds a doctoral degree from Pace University, the Ivan G. Seidenberg School of Computer Science and Information Systems. Her dissertation topic was Keystroke Biometric Identification on Long-Text Input. Publications in this area include peer-reviewed journal articles, and a co-authored book chapter, in Behavioral Biometrics for Human Identification: Intelligent Applications. Dr. Villani has been actively seeking funding internally and externally to address gender disparity and broaden participation in the Computing Programs at FSC. The money raised through campus grants and other funding sources was used to provide Women Student Orientation programs, and to take students to women in computing events. Dr. Villani has been active publishing and presenting these experiences in an effort to share within the research community and to ultimately broaden participation. Dr. Villani is the co-advisor of the Supporting Women in Computing Club where she has mentored many women students in the program. Dr. Villani is the recipient of the Chancellor's Award for Teaching Excellence, 2012. Prior to joining FSC, Dr. Villani had a 15 year computer consulting career in the Risk Management and Insurance Industry.

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Nur Dean is an Assistant Professor in the Computer Systems Department at Farmingdale State College in New York. She obtained her PhD in Computer Science from The Graduate Center, City University of New York and holds an M.S. in Applied Mathematics from Hofstra University in New York. With a primary research focus on Game Theory and Social Networks, Dr. Dean also harbors a keen interest in Machine Learning classification. Passionate about mentoring undergraduate students, she has guided many in the realms of Game Theory and Machine Learning. Additionally, Dr. Dean has contributed her expertise as a judge at regional events such as the New York State Science and Engineering Fair (NYSSEF) and the WAC Lighting Invitational Science Fair.

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Moaath Alrajab serves as an Assistant Professor in the Computer Systems Department at Farmingdale State College, SUNY, New York. He earned his Ph.D. in Computer Science from the University of Leeds, UK, and completed his Master of Science in Mobile Computing at Bradford University, UK. His undergraduate degree in Electronic Engineering was attained from Albaath University in Homs, Syria. Before transitioning to academia, he worked as a software engineer.

Dr. Alrajab's research focuses on Machine Vision and AI. He is dedicated to supporting women in computing and advocating for increased diversity in the field. Additionally, Dr. Alrajab holds the position of chair for the department curriculum committee and is a member of the college-wide curriculum committee.

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Arthur Hoskey is a Professor of Computer Systems at Farmingdale State College in New York. He received his Ph.D. in Computer Science from the City University of New York Graduate Center and received his B.A. in Psychology from the State University of New York at Purchase. Dr. Hoskey worked as a software engineer prior to starting his academic career.

Dr. Hoskey's primary line of research has been around innovative pedagogical methods. One line of research was a collaboration with faculty from multiple State University of New York colleges on a project to explore and develop a semi-standardized and accessible introduction to computer science course (SUNY IITG funded research), focused on teaching computational thinking skills. Another line of research was the development of a simulated operating system, SimpleOS, that allowed students to run basic programs and visually see the state of the simulated memory, registers, and process queues in order to facilitate student learning. Dr. Hoskey has also collaborated with the Farmingdale State College Center for Applied Mathematics and Brookhaven National Laboratory on an undergraduate research program in the area of Signal Analysis. Dr. Hoskey received the 2017 Chancellor's Award for Excellence in Teaching from the State University of New York.

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Ilknur Aydin is an Associate Professor of Computer Systems at Farmingdale State College, SUNY, New York. Dr. Aydin's research is in the general area of wireless and mobile networks with a focus on transport layer issues including multihoming, SCTP, congestion control, and network coding. Dr. Aydin has mentored undergraduate and high school students on research projects that involve the use of Arduino boxes and Raspberry Pi's in the context of Internet of Things, and the use of public testbeds such as CloudLab and FABRIC for WiFi and cellular networking research. Dr. Aydin has been a vivid supporter of women in computing and increasing diversity in computing. She has been the co-faculty advisor for Women in Computing club at Farmingdale, contributed in Grace Hopper Celebration as a technical committee member and reviewer. Dr. Aydin has published and presented in peer reviewed venues about women in computing and broadening the participation over a decade. Dr. Aydin is the 2023 recipient of the Farmingdale Foundation Excellence Award for faculty service.

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Abstract

Interest in computing related majors has grown amongst college students in the United States. Despite this growing interest, retention and graduation rates are a concern for many regional public universities such as Farmingdale State College (FSC). Educational researchers have demonstrated the benefits of increasing student sense of belonging (SoB) and academic self-concept (ASC) on academic outcomes. This study explores the interaction between implementing collaborative learning techniques (CoLT) in a CSC 101 Introduction to Computing course with students' SoB and ASC. Given the social constructivist perspective that frames CoLTs and these techniques' ability to engage students authentically in course content, the implementation of CoLTs is hypothesized to positively impact students' SoB and ASC. Students in the fall 2023 section of CSC 101 piloted a pre- and post-survey to measure their SoB and ASC. Additionally, students were interviewed about their experiences on the CoLT course. This survey will be implemented in three sections of the CSC 101 course in spring 2024. This paper presents the overall research design and preliminary survey responses from fall 2023. Preliminary results demonstrate a positive impact on SoB and ASC for students. These results provide encouraging motivation to further investigate how CoLTs may impact student retention and academic performance in computing majors.

1. Introduction and Background

Computer Science and Computer Programming and Information Systems are complex subjects that require critical thinking and problem solving for students to succeed. Students often become frustrated early in their major or miss mastering fundamental concepts in the early classes, which result in constant review in upper-level courses or students dropping from the major. [1] demonstrate the difficulty in lecture-based teaching methods on student achievement in computer programming courses. A "rule-drive, top-down teaching approach" (p. 2) plagues computing courses at the collegiate level [1]. These teaching methods limit students' practice with

independent inquiry, problem solving, and thinking critically. As such, alternative pedagogies might be needed to support students in learning complex subjects such as Computer Science and Computer Programming and Information Systems.

Collaborative learning is a pedagogical approach that intentionally designs learning for students in group formats [2]. Epistemologically, collaborative learning stems from a social constructionist perspective that posits "groups construct knowledge" together and peers have the capacity to "make and experience meaning together" [2, p. 8]. It shifts learning from an "instructor-centered classroom" to "students teaching one another" [3, p. 935]. Utilizing a diversity of perspectives, collaborative learning causes socio-cognitive conflict, where students have different ideas about the same concept. Students incorporate new learning because of negotiating this socio-cognitive conflict [3] and co-constructing meaning.

Students' sense of belonging (SoB) and their academic self-concept (ASC) have long been studied as proxies for student retention and academic achievement. In his seminal work, [4] posits that college students' academic achievements are positively impacted when they have a stronger sense of belonging. Furthermore, students who feel a stronger peer-to-peer connection demonstrate higher levels of engagement within their courses [5]. Secondly, students' academic self-concept, or their perception of their academic abilities and their academic identity, is influenced by their environment [6]. A student experiences an opportunity for social comparison and a method to judge one's academic abilities through engagement with one's peers and classroom setting. Overall, students who have a stronger sense of belonging and a more positive academic self-concept may experience increased academic outcomes.

Given the social context of both sense of belonging and academic self-concept, research is needed to understand the role collaborative learning (e.g., peer tutors, collaborative class activities, and collaborative laboratory assignments) can play in students' experience of the computing classroom. The objective of this research project is to explore student perceptions of the impacts of implementing collaborative learning techniques (CoLT) in computing courses on student experience, sense of belonging, academic self-concept, and academic performance. Based on a review of the relevant literature, the following hypotheses are developed.

- CoLT students will have an increase in SoB at the end of CSC 101 Introduction to Computing course.
- CoLT students will have an increase in ASC at the end of CSC 101.
- CoLT students will be likely to remain in the Computer Science program at the end of CSC 101.

At present, this study is a work-in-progress. The study conceptualization, literature review, and methods are presented below. In addition, preliminary data results from the pilot in fall 2024 are discussed.

2. Related Work

Collaborative learning techniques as a pedagogical approach. Collaborative learning is a pedagogical approach that prioritizes interaction among peers as a key component of student learning. Students work together in groups on a common project, problem, or topic, and support each other to master the lesson's objectives. [7] lists the following features of collaborative learning groups: (1) positive interdependence, (2) individual accountability, (3) heterogenous, (4)

shared leadership, (5) shared responsibility for each other, (6) task and maintenance emphasis, (7) direct instruction of social skills, (8) teacher observation and intervention, and (9) group reflection on their effectiveness. These core features require students to utilize their psychosocial skills to negotiate their learning. [8] notes that while collaborative learning often takes place in group work, not all group work is collaborative. At times, students might be independently working on a task, but they have joint attention with each other in the group. Certain stages of group work may be collaborative and certain stages may not. Ultimately, all group members are working towards a shared academic goal.

For the purpose of this paper, the following descriptions of the types of collaborative learning techniques are used in this study.

- *Group work with defined roles:* [9] found that defining roles for students in group work facilitates two critical elements: positive interdependence and individual accountability. By assigning roles, students are required to depend on each other in task completion and be accountable for fully participating in their share of the group work. In this course, defined roles were used throughout the collaborative activities. For example, in a History of Computing Activity, students participated in the in-class activity by having defined roles and responsibilities. Some students were responsible for the oral presentation, others had to identify new discoveries in the content, while others needed to contextualize the events in their research.

- *Peer Assessment and feedback:* Providing and receiving assessments from one's peers can provide a variety of benefits for students involved in the peer assessment process. Students may have the opportunity to reflect, self-assess, and co-construct subject matter knowledge. Students' confidence in the subject matter may also increase [10]. While these benefits have not been found to be universal, this study utilized collaborative learning techniques to build a trusting environment in which peer assessment could offer these positive benefits for students. For example, in a Hardware and Software Activity, students were required to categorize items as input, output, or both. Group members were required to assess their peer's work and provide a justification for changing the categorization.

- *Instructor-led discussion:* [11] found that peer instruction and collaborative learning techniques can have positive impacts on students' understanding of computer science when paired with instructor-led discussion. By providing an opportunity to explore the content with their peers, and then leading discussions to correct any misunderstandings, students experienced larger learning gains, particularly for weak and average students. For specific collaborative learning techniques in this course, the instructor led discussions afterwards. For example, when problem sets included multiple approaches to solve the problem, the instructor led a discussion on the different approaches.

Sense of belonging. [4] defines a sense of belonging as "students' perceived social support on campus, a feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the campus community or others on campus such as faculty, staff, and peers" (p.4). Belonging is often mediated by an individual's perception of their relationship with others in particular settings [12]. In recent years, a sense of belonging has emerged as a critical area of research within higher education. Sense of belonging

has been correlated with higher academic performance, greater persistence, engagement in college community, development of peer and faculty mentorship relationships, and psychological well-being [5, 13, 14, 15, 16].

Academic self-concept. Perception of one's academic abilities and one's academic identity constitutes a person's academic self-concept. [6] highlights the impact that a student's environment can have on the development of a positive academic self-concept. By engaging with peers and faculty within one's discipline, students develop a schema by which they evaluate their academic abilities. However, it is not pure self-evaluation. An academic self-concept, while providing students with an understanding of their own academic abilities, also influences how one feels about their ability and how they respond to academic challenges [17, 18]. In higher education settings, [19] found that students who report higher levels of academic self-concept also report higher levels of persistence, retention, and academic achievement.

3. Research Methodology

Study Context. Over the last decade, the enrollment in the Computer Programming and Information Systems (CPIS) major at FSC has doubled reaching about 800 students in spring 2024. Each year, there is a growing interest in computing degree programs at this regional, state institution of higher education. As one of the technology colleges of a large, state system with sixty-four institutions, FSC has also been the recipient of a $75 million investment in facilities dedicated to computing degree programs. To complement this interest, FSC launched a Computer Science program in fall 2021 offered as a separate degree program from the CPIS program within the newly to-be-created Division of Computing in the School of Engineering.

The Collaborative Learning Techniques (CoLT) Curriculum Project was launched in summer 2023 by several faculties within the Computer Systems department at FSC and an external educational researcher. During the summer 2023, Computer Science faculty members met to design and source collaborative learning pedagogies to implement in their Computer Science sequence, which included CSC 101(CS 0), CSC 111 (CS 1), and CSC 211 (CS 2) courses. Additionally, this group collaborated with a private college in the Midwest that had success impacting enrollment through adoption of collaborative learning techniques in their introductory sequence of Computer Science courses. Subsequently, a pilot was designed to implement 24 collaborative assignments in the CSC 101 course at FSC over its 28 class meetings in the fall 2023 and spring 2024 semesters. A peer tutor, who was an upper-level Computer Science major, was selected to assist in facilitating the collaborative learning assignments in the fall 2023 pilot. This peer tutor was compensated with a $1000 stipend. This paper presents results from the first semester of a two-semester pilot with only one section of CSC 101 offered in fall 2023.

CSC 101 course is an introductory Computer Science class that focuses on critical Computer science topics. The ACM/IEEE CC2020 [20] guidelines for introductory Computer Science course content guided the curriculum development for CSC 101. The catalog course description and course learning outcomes are listed below.

"Catalog Course Description:
Computers have become a part of everyday life across many academic disciplines. In this course, students will acquire a broad knowledge of the computer science and information technology

fields. Topics covered will include basic computer concepts, an overview of computational and algorithmic thinking, and an introduction to using computers to solve real-world problems. After completing this course, students will be prepared to apply computer concepts to other fields.

Course Learning Outcomes:

At the completion of this course, students will be able to

1. Identify the areas of a computer system: software, hardware, processes, storage, inputs, and outputs.
2. Identify and demonstrate computational thinking techniques.
3. Demonstrate a familiarity with basic concepts relating to the areas of computer architecture, operating systems, networking, and database.
4. Use and demonstrate correct computer-related terminology.
5. Design, implement and test simple computer programs to solve real-world problems.

Topics covered include: Computer Science, History of Computing, Hardware, Software, Virtual Machines, Computer Systems Components and Organization / Architecture (Von Neumann), Operating Systems, Algorithms, Flowcharting, Pseudocode, Binary Numbering System and Data Representation, Boolean Logic & Gates, Computational Thinking, Networking, Python Programming and logic including variables, functions, iterative constructs, searching recursion, scheduling, graphing and introductory relational database concepts."

Data Collection and Analysis. The main goal of this paper is to identify the correlation of collaborative learning techniques with students' sense of belonging (SoB), academic self-concept (ASC), and academic performance. This case study is conducted on a group of mixed men and women from diverse backgrounds enrolled in a CSC 101 level course. Ultimately, the goal of this project is to increase the enrollment and retention of students in computing degree programs at FSC. Class sizes are typically under twenty-five students per section and represent several gender identities, although significantly more men enroll in computing courses. The CSC 101 course fills a liberal arts and sciences course requirement and, as such, the student population is usually mixed major with Computer Science as the dominant group. A program containing all student names from a section is created and run to randomly organize the groups for each class session. This gives students an opportunity to work with different members of the class each time the class meets.

To measure SoB, researchers applied the Revised Sense of Belonging Scale from [21] which is a standard self-report tool. The Revised SoB Scale is a 5-point Likert scale across four factors: Perceived Peer Support (8 items), Perceived Classroom Comfort (4 items), Perceive Isolation (4 items), and Perceive Faculty Support (10 items). To measure ASC, researchers applied the Academic Self-Concept Scale developed by [22]. The ASC Scale is a 40 item, 4-point Likert scale. Each of the 40 items was coded as positive academic self-concept (e.g. "I consider myself a good student," "All in all, I feel I am a capable student") or as negative academic self-concept (e.g. "I feel I do not have the necessary abilities for certain courses," "No matter how hard I try I do not do well in school").

Data were collected from one section of CSC 101 which had 23 enrolled students in fall 2023. The pre-survey was administered within the first two weeks of the semester and elicited 17 responses.

The post-survey was administered within the last two weeks of the semester and elicited 18 responses.

Responses were collected with students' campus ID numbers to match pre- and post-survey responses. Once matched, responses were de-identified using a unique ID for each student. The fall 2023 survey administration yielded 11 matched pre- and post-survey responses. Due to the small sample size in these courses, pre-and post-survey data analysis on matched responses will not be presented at this time. Results below demonstrate all student responses. Students were provided with the opportunity to interview. One participant agreed to participate in the fall 2023 interview. To maintain the anonymity of the one participant, interview data will not be reviewed in this paper. Data collection will continue in spring 2024 with three sections of the course being offered. This will include up to 75 potential study participants for both the survey and interview data collection procedures. For survey responses from both the fall 2023 and spring 2024 semesters, matched survey responses will be analyzed with a paired t-test.

4. Preliminary Results

Of the 23 potential participants, 17 (73.9%) of the participants completed the pre-survey and 18 (78.3%) of the participants completed the post-survey. Pre- and post-survey means for each factor of the SoB scale are reported below (Table 1). Pre- and post-survey means were found for each of the factors on the sense of belonging scale. The four factors are peer support, classroom comfort, peer isolation, and faculty support. Three of the factors (peer support, classroom comfort, and faculty support) experience an increase in the means between the pre- and post-survey responses. One factor, peer isolation, experienced a decrease. This decrease is to be expected as peer isolation is an indicator that students lack a sense of belonging while the other three factors indicate a greater sense of belonging among students.

	Pre-Survey Mean(n=17)	Post-Survey Mean (n=18)	Change (%)
Peer Support	2.19	3.03	+38.34%
Classroom Comfort	3.65	4.35	+19.18%
Peer Isolation	3.46	3.10	-10.40%
Faculty Support	3.21	3.45	+7.48%

Table 1. Pre- and Post-survey Means of Students' Sense of Belonging

Pre- and post-survey means were found for items categorized as positive academic self-concept and items categorized as negative ASC (Table 2). Items grouped as positive academic self-concept experienced an increase. Item grouped as negative academic self-concept also experienced an increase, although the increase was smaller.

	Pre-Survey Mean (n=17)	Post-Survey Mean (n=18)	Change (%)
Positive Academic Self-Concept	2.72	2.92	+7.35%
Negative Academic Self-Concept	2.40	2.65	+2.65%

Table 2. Pre- and Post-survey Means of Positive and Negative Academic Self Concept

5. Discussion and Limitations

The results of this study are preliminary as the study is currently in progress. This paper details the results of the pre- and post-survey from the first semester pilot in fall 2023. Three more course sections will participate in this study in the spring 2024 semester, yielding potentially 75 more future participants.

At present, the results of this study are insufficient to evaluate the hypotheses. However, while the sample size was small, the means of each sense of belonging factor changed in the direction that would be supportive of the hypothesis. Students' average score of peer support, classroom comfort, and faculty support all increased from the pre- to the post-survey. Students' average score of peer isolation decreased from the pre- to the post-survey. Future research will determine if this is a factor of time in the class or if the collaborative learning techniques specifically played a role in these changes.

For academic self-concept, students' mean scores of positive statements of academic self-concept slightly increased. However, students' mean scores of negative statements of academic self-concept also increased. This increase introduces additional questions about the impact of students becoming more knowledgeable of a subject matter on their perceptions of their academic abilities. As students learn more about the depth and complexity of the field, do they feel less confident in their academic abilities? Students' academic self-concept might have been inflated at the beginning of the semester and as they learned more about what they did not know in the field, this new understanding might have negatively impacted them. Future research will help illuminate the role of collaborative learning techniques in understanding students' academic self-concept, especially in early academic major courses.

As a quasi-experimental study, there are limits to validity of this work-in-progress study.

Different Instructors. While the data presented above refers to a single section with one instructor, the full pilot study (inclusion of fall 2023 and spring 2024 semesters) will include two instructors over the course of two semesters. As such, it will be a multi-instructor study. Different instructors may differ in their preference and modes of instruction. Starting in spring 2024, both instructors will be teaching CSC 101 Introduction to Computing. They will follow the same teaching plan and share lecture materials to minimize differences. They met weekly during the preparation of the materials and will meet weekly throughout the semester of implementation. Both instructors utilize an assignment system to assign the same questions to students in each course section. All assessments are shared among the faculty group. Additionally, based on student feedback received weekly, the instructors will adjust their lesson plans accordingly.

Different Students. Each class does not contain the same number of students, the same majors, and the same academic preparedness and exposure to computer science. These uncontrolled variables may impact the study's results. As this course also fulfills a liberal arts and sciences requirement, computing majors and non-computing majors are both included in the study. However, these courses are required courses for majors in Computer Science and Computer Programming and Information Systems.

Sample Size. One of the major limitations for this study is the sample size. At present, this study is a work in progress with only 11 collected matched responses among the pre- and post-surveys. Pre- and post-survey responses from an additional three sections of CSC 101 will be collected in the spring 2024. This provides the opportunity for an additional 75 study participants through the spring semester. Hopefully, this will yield a significant increase in the number of matched responses so additional advanced statistical analysis of the data can occur.

6. Future Work and Conclusions

This study presented the initial survey implementation of a longer-term study. These data collection procedures will be implemented in the spring 2024 semester, expanding to three sections of CSC 101 (CS 0). In the coming semesters, this study will expand to CSC 111 (CS 1) and CSC 211 (CS 2). Future work will also include qualitative interview data to answer questions regarding sense of belonging and academic self-concept that might not be readily seen from the quantitative data collection. For example, students' understanding of their academic self-concept has the potential to be negatively impacted as they learn more about what they do not know in the field.

Additional research inquiries resulted from the preliminary interview analysis. These research inquiries include investigating faculty perceptions of CoLTs in introductory courses, faculty perceptions of student preparedness for higher-level courses after taking CSC 101, CSC 111, and CSC 211 with CoLTs embedded, and student interviews about the impact of CoLTs and active learning pedagogies after experiencing remote learning due to COVID-19 restrictions. This study is not designed to pursue such lines of research inquiries. However, the researchers note the potential connections to these areas from this study.

While this paper presented limited data from the one semester pilot study, it provides encouraging motivation to further investigate how collaborative learning techniques impact students' sense of belonging, academic self-concept, and their retention in computing majors and their academic performance in those majors. Its preliminary results offered up additional questions for the researchers to incorporate in their future data collection procedures and analyses. Most specifically, qualitative interview questions provide an opportunity to investigate why and how academic self-concept changes for students over the course of the semester. Future research that incorporates a larger sample size and qualitative interviews is needed to fully understand this interaction. In summary, this work provides a solid foundation for future research in how CoLTs can impact students in introductory computing courses and how faculty members can utilize these pedagogical tools to grow and support their computing degree programs at the undergraduate level.

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