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INFORMATION SYSTEMS EDUCATION JOURNAL

Teaching Professionalism and Ethics in IT by Deliberative Dialogue

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Abstract

Cyberethics in IT remains a hot-button issue for higher education institutions and governments worldwide as high numbers of violations continue to surface globally. Since unethical behavior in IT knows no boundaries and college students are a growing portion of the population of cybercitizens studies in cyberethics is a necessity. By reinforcing professionalism and ethics as one of their main assessment criteria of the field, the globally recognized council, the Accreditation Board for Engineering and Technology (ABET) has already underscored the importance of professional and ethical responsibility. This study derived from the significance of these concerns and explored this very concept of professionalism and cyberethics in the field of Computer Science by means of using deliberative dialogue in a required Computer Science undergraduate core course. While using the dialogue method, the course adapted case-based learning together with ethical decision-making throughout the entire semester. Both numerical and textual data were collected from the students throughout the course. The findings revealed that students found more value in the dialogue forums than a traditional lecturing method resulting in gaining mastery in professionalism and theories of ethics as part of their course learning outcomes. The findings indicated that student self-esteem in the subject matter improved as well. In addition, critical thinking skills of students showed a significant improvement. While students felt that they became more receptive to diverse viewpoints, they also felt more confident in public speaking.

Keywords: ethics, professionalism, critical thinking skills, cyberethics, IT.

1. INTRODUCTION

The advent of information and communication technologies not only marked the beginning of an era of powerful developments with a myriad of added benefits, but also brought with it increasing concerns of multitude of threats. Cyberspace has been defined as a community built on top of the Internet where sometimes users confuse their lives with their cyberspace existence (Lessig, 2018). While there is no sharp line dividing cyberspace from the Internet, there are common areas of concerns such as regulations by codes, stakeholders, attitudes, privacy, and security all of which need to be tackled by the frontiers of protection by cybercitizens (Lessig, 2018; Reynolds, 2014).

Spinello (2017) identified two underlying assumptions of the era of cyberspace: "1) the directive and architectonic role of moral ideals and principles in determining responsible behavior in cyber space, and (2) the capacity of free and responsible human beings to exercise some control over the forces of technology (technological realism)" (p.2).

Cyberspace raises questions related to the status of information as public or private property and its potential for simultaneously strengthening democracy and enabling new forms of surveillance that threaten privacy (Fuchs, Bichler, & Raffl, 2009). Since unethical behavior in IT knows no boundaries and college students are a growing portion of the population of cybercitizens studies, cyberethics becomes a necessity. By reinforcing professional and ethical responsibility the Accreditation Board for Engineering and Technology (ABET) has already underscored the magnitude of the concerns and the significance of teaching professionalism and cyberethics (ABET, 2017a, 2017b).

This study was derived from the significance of these increasing concerns for cyberethics and explored the experiences of students related to mastering professionalism and ethics in a Computer Science course. The data were collected from an undergraduate core course, *Professionalism and Ethics,* as part of a public university Department of Computer Science curriculum. The course objective was to provide students with a platform to understand the professional and ethical issues they would encounter in the workplace and in assuming their responsibilities in the profession.

As part of a 14-week course deliberate dialogue was adapted for case-based learning. Critical-thinking Assessment Test (CAT) introduced by Tennessee Tech (2018) was used throughout the course to determine student improvement in the area of critical thinking skills. The CAT assessment was selected since the criteria ranging from "evaluating information" to "communication" were pertinent to the profession. In addition, during the 14 weeks two forms were used to evaluate the value of deliberate dialogue and to critique the deliberative dialogue method. While one form collected numerical data, the second form collected rich textual data.

The student experiences revealed that deliberate dialogue was valuable when it came to mastering the course content by promoting interactions among students. Additionally, the method was instrumental in adding a multitude of skills related to professionalism and ethics.

2. LITERATURE REVIEW

National Center for Education Statistics (National Center for Education Statistics [NCES], 2018a) data on the overall college enrollment rate for young adults (18- to 24-year-olds) indicated an increase of 35% from 2000 to 41% in 2016. During this period, the rate increased from 26% to 31% at four-year institutions but did not change measurably at two-year institutions. The immediate college enrollment rate for high school completers increased from 63% in 2000 to 70% in 2016 (NCES, 2018b). Enrollment in the U.S. institutions of higher education increased to 20.2 million in the fall of 2015, followed with declined enrollment of 17.8 million in the spring of 2018 (The National Science Foundation [NSF], 2018; National Student Clearinghouse [NSC] Research Center, 2018). Data on the international undergraduate student enrollment during the same period revealed that international undergraduate enrollment increased consistently from nearly 350,000 in the fall of 2012 to nearly 451,000 in the fall of 2016, but dropped to about 441,000 by fall 2017.

Related to the field of Computer Science, similar enrollment growth was reported: "across the United States and Canada, universities and colleges are facing a significant increase in enrollment in both undergraduate computer science (CS) courses and programs" (Computing Research Association [CRA], 2017, p.1). As these numbers build up, it becomes an ethical and legal obligation for Computer Science programs to cultivate the right mindset for cyberethics. Including the challenges of economical impact, workforce demands, and immigration policy amendments, universities and colleges are saddled with bigger responsibilities not only in preparing their students for a globalized workforce, but also training them to make ethical decisions.

Professionalism

Professionalism is defined as communicating effectively and appropriately while finding ways to be productive and conducting oneself with responsibility, integrity, accountability and excellence (U. S. Code, 2018; The U.S. Department of Labor, 2018).

Kultgen (1988) reported that "sociologists have not found a scheme of classification that results in generalizations with any significant predictive power" (p.58). Various sociologist collected and summarized many characteristics which are incorporated in more than one definition (Kultgen, 1988).

However, from the recent research, characteristics of professionalism is not just about possessing a college degree, title, certificate, and technical skill, but also includes a number of important characteristics applied to cyberspace and any type of business. Joseph (2018) listed 10 characteristics of professionalism as: appearance, demeanor, reliability, competence, ethics, poise, phone etiquette, written correspondence, organizational skills, and accountability. These characteristics comprise the needed basics for any professional entering into the 21st century workforce. The consensus is that students would be capable of earning these characteristics before students step into the workforce. This study took these views into account to analyze the IT experiences of students in their personal lives and working environments.

Cyberethics

In the real world, people live and work by obeying the laws of civil society, social perspective behaviors, and governmental regulations. Reynolds (2014) defined ethics as a set of beliefs about right and wrong behavior within a society. Whether it is doing the right thing or treating others the way one would like to be treated students need to be coached in ethical conduct in accordance with the standards of their profession.

In tackling the field of ethics, whether part of a science or a liberal arts curriculum, university programs reveal more similarities than dissimilarities. Thelin (2017) reported "one such mischaracterization is that "STEM" (science–technology–engineering–math) fields are apart from the liberal arts" (p. 54). This dis-engaged situation could impair the safety and welfare of students within a student culture since issues like sexual harassment, physical harm, and bodily injury along with the humiliation, exclusion, and rejection are the elements that cause alarm (Thelin, 2017).

Extending ethics to cyberspace, cyberethics is defined as four constraints which regulate users' behavior and include laws, norms, the market, and code (Lessig, 2018). In the regulation of cyberspace, the persons who play directive roles "should guide and direct the ways in which code, laws, the market, and social norms exercise their regulator power. The value of human flourishing is the ultimate constraint on our behavior in real space and in cyber space" (Spinello, 2017, p.7).

Since professionals in IT use tools which affect lives of others, all constituents are obliged "to minimize negative consequences of computing systems, including threats to health and safety" (Association for Computing Machinery [ACM], 2018, para. 1). It is a legal obligation for higher education programs to enforce these moral imperatives "when designing or implementing systems, computing professionals must attempt to ensure that the products of their efforts will be used in socially responsible ways, will meet social needs, and will avoid harmful effects to health and welfare" (ACM, para 1).

In addition to ACM moral imperatives, criteria for ABET set by ABET underscores the issue of cyberethics (ABET, 2017a, 2017b). These assessment criteria cover a wide variety of fields including Cybersecurity Engineering and Engineering programs; including, but not limited to, "Security," "Cybersecurity," "Computer Security," "Cyber Operations," "Information Assurance" or similar modifiers in titles related to "Information Security" (ABET, 2017a, p. 42).

ABET (2017a) reinforces professionalism and ethical behavior when developing curricula: "the curriculum must provide both breadth and depth across the range of engineering and computer science topics necessary for the: consideration of legal, regulatory, privacy, ethics, and human behavior topics as appropriate to the program" (p. 43). The importance of these steps demonstrates that teaching professionalism and ethics should be a priority as it is a moral imperative and a legal obligation for all higher education stakeholders.

Deliberative Dialogue

Deliberative dialogue is defined as "a face-to-face method of public interaction in which small groups of diverse individuals exchange and weigh ideas and opinions about a particular issue in which they share an interest" (American Institutes for Research [AIR], 2018, para. 2). In addition, deliberative dialogue provides a way for people of diverse views and experiences to seek a shared understanding of problems and to search for common ground for action (National Issues Forums [NIF], 2018). London (2018) explained that "deliberative dialogue differs from other forms of public discourse, such as debate, negotiation, brainstorming, consensus-building — because the objective is not so much to talk together as to think together, not so much to reach a conclusion as to discover where a conclusion might lie" (para.2).

There are increasing numbers of enterprises, institutions, and universities which apply dialogue to support company/campus development, and/or teaching strategies. For example, North Carolina Compact has used deliberative dialogue as a tool to build citizenship and community (Campus Compact, 2018). Wake Forest University (WFU) and West Kentucky University (WKU) utilize a deliberative dialogue program which has become central to the way in which the campus builds a community and engages in decision-making (WFU, 2018; WKU, 2018). Lone Star Community College in Texas also has many successful projects to motivate student learning in various courses using deliberative dialogue forums (Lone Star Community College, 2018). The college provides a way for community members of diverse views and experiences to seek a shared understanding of problem and search for common ground. Typical classroom setting dialogues are led by trained faculty, staff, and student moderators. Three or four broad approaches to a problem are expected to evolve from the discussion guideline. The students approach the issue by presenting the overall problem, examining what appeals to the team or what concerns them and what costs, consequences, and tradeoffs may be incurred in following that approach (Lone Star Community College).

Case-Based Learning

Without taking-risk there is no incentive for the discovery of new ideas or ways of thinking for this new generation of students. Raley and McKay (2017) echoed the intellectual risks for students increased through accountability for their own learning as well as that of their classmates. Students have to engage in complex thought processes, analyze and weigh disparate competing ideas to form sound, logical arguments which they could then present and defend (Krochmal & Roth II, 2017).

The course used in this study emphasized case-based learning by adapting the ethical decision-making process throughout the entire semester. Students worked in groups on each case study. Current events together with theoretical and foundational readings were used to make up the case studies. Krochmal and Roth II (2017) suggested "case studies related to human or environmental health are deeply integrative, combining aspects of science, public policy, ethics, business, economics, and potentially countless other disciplines" (p.113).

The new ways to approach resolving issues and providing analysis could be the best practice for future workforce employees. Bellas (2017) reported that one of the best indicators of a student's success after college "is the level of empowerment they feel to navigate the world with a sense of agency" (p.79).

One example of empowerment is succeeding within the college culture which serves as a central topic of American tradition of memoirs and fiction. This genre is rich with examples of concerns which provide social and behavioral scientists with an array of sources for systematic scholarly research (Thelin, 2017). Concerns like risk-taking, conformity, creativity, exploration, confidence, timidity, working within forms, fear of failure, avoiding hard work, learning how to navigate bureaucracies, as well as acquiring facts merely hint at the variety and often conflicting array of mixed messages college curriculums convey (Thelin).

For instance, training officers in the U.S. Navy and Marine Corps is another example wherein ethical training is necessary. Midshipmen will face moral, ethical, social, and inter-personal challenges as soon as they join their first unit. Therefore, these issues should be tackled head-on in classroom discussion (Gibb II, 2017).

Likewise, failing to mentor science students in thorough and universal questioning, critical thinking, and objective analysis represents a serious failure of our higher education system (Krochmal & Roth II, 2017)

Decision-Making Process

As part of the course, students were involved in ethical decision-making processes. The course used the five-step ethical decision-making process (Reynolds, 2017) related to the IT fields as follows:

Step 1. Develop Problem Statement: Gather and analyze facts without making any assumption. Identify stakeholders affected by the decision.

Step 2. Identify Alternatives: Involve others including stakeholders while in brainstorming stage.

Step 3. Evaluate and Choose Alternatives: Evaluate what laws, guidelines, policies, and principles would apply to each alternative. Foresee any possible impact on the employees, the organization, and other stakeholders.

Step 4. Implement Decision: Develop and execute an implementation plan. Provide leadership to overcome resistance to change.

Step 5. Evaluate Results: Evaluate results against selected success criteria. Predict any unintended consequences.

Each group of five to seven students practiced the five steps of the decision-making process to provide their group alternatives for each case-study. Moreover, the ethical theories and approaches were required to be included in their discussion.

Critical Thinking Skills

The course reinforced critical thinking skills as ample resources prove high impact educational practices involving students in active learning can contribute to gains in critical thinking. However, there is still a disconnect between the skills faculty want to develop using these activities and the way students are assessed in those courses (Haynes, Lisic, Goltz, Stein, & Harris, 2016). Haynes et al.(2016) argued "the assessment of students' critical thinking skills using an "authentic" faculty driven assessment where faculty can see student responses and simultaneously providing faculty development support can motivate faculty to focus more on the improvement of students' critical thinking skills" (p.46).

This study used the CAT introduced by Tennessee Tech (2018) which was "developed with input from faculty across a wide range of institutions and disciplines, with guidance from colleagues in the cognitive/learning sciences and assessment and with support from the National Science Foundation (NSF)" (para 1).

The Tennessee Tech faculty group also examined the validity of the CAT by comparing student performance on the test with other measures of academic performance to reveal critical thinking skills (Stein & Haynes, 2011).

The CAT guidelines are based on the following criteria: (a) Evaluating Information, (b) Creative Thinking, (c) Learning and Problem Solving, and (d) Communication. For criteria (a) and (c), the key terms regarding professionalism and ethics were evaluated and students were awarded points to determine if each mentioned term was supported with solid references.

For criteria (b) and (d) the points were issued based on the creativity of each proposed alternative solution and how these ideas were evaluated by the students. The pre-CAT assessment grading points are listed in Appendix A, and the post-CAT assessment grading points are listed in Appendix B.

3. METHODOLOGY

To deliver the concept of professionalism and cyberethics and increase the critical thinking skills for the undergraduate students the deliberative dialogue teaching method was used for a required Computer Science core course in the spring 2018 semester. The assessment instruments were designed to evaluate two areas. One was the individual learning growth in critical thinking skills assessed through completing four CAT exams throughout the semester. The second was two surveys regarding the deliberative dialogue format conducted at the end of the semester. The semester ending surveys included Form I, a quantitative questionnaire, and Form II, a qualitative discussion format.

The course initially had a total of 32 students with 31 students completing the course. Three were female and the remaining 28 were male. All students were seniors majoring in Computing Science, Computer Software Engineering Technology, or Digital and Cyber Forensic Engineering Technology under the Department of Computer Science.

Data Collection

The researchers collected both numerical and textual data by means of two sets of instruments throughout the course including the CAT Form I, and Form II to explore student experiences related to learning professionalism and ethics. This course adopted the textbook of *Ethics in IT* (5th Edition) by Reynolds, G. W.

A total of four CAT exams were distributed and required to be submitted through the learning management system, Blackboard. Pre-CAT and post-CAT exams were scheduled at the beginning and at the end of the semester respectively.

During the semester, two CAT exams covering five teaching topics were assessed. The students received the case study for CAT on a Thursday class and submitted their essays by the following Tuesday.

The principal researcher (who was also the instructor of the course) graded the CAT assessments collected from students according to the guidelines. After studying a given case, students submitted essays to illustrate their thinking process. The expected key words and concepts from the CAT included the ethical theories, approaches, and five steps of the decision-making process. The expected criteria were tallied to total their CAT scores.

Classroom Teaching Practices
The format of teaching pedagogy related to deliberative dialogue and CAT was designed in three phases:

1. Educate the students to be competent moderators in directing group discussions. Faculty members were trained before implementing this teaching strategy.
2. Select appropriate case studies for each learning module. Each separate study discussion was led by a different moderator.
3. Complete CAT assessment for one pre-CAT, one final CAT, and two CATs covering individual learning modules.

In addition, at the end of the semester two forms of survey were given to students. Form I collected data on the value of the deliberative dialogue forums, and Form II asked for constructive critique about the focus group, deliberative dialogue teaching method.

Form I was put up online at the beginning of the class. A total of 20 students submitted their input in the first five minutes of the class. Thirty minutes prior to class ending, every group of five students participated in the Form II survey. A total of 25 students presented and participated in the team discussions.

Form I
Form I was a quick online survey made up of five statements based on a five-point Likert-scale using Google Form. The students taking the course reviewed these statements and provided their scores based on their experiences concerning deliberative dialogue in learning professionalism and ethics in IT fields. The survey included the following instructions:

Form I: Please provide a score of 1 to 5 for each statement. 1 being the least value and 5 being the highest value.

1. *I appreciated the Deliberative Dialogue forums more than a traditional lecturing method.*
2. *I have gained a good learning experience in comprehending the ethic theories through the Deliberative Dialogue forums.*
3. *This Deliberative Dialogue forum improves my critical thinking skills.*
4. *I have learned to accept and understand diverse views and points.*
5. *I have gained self-confident in public speaking and improved self-esteem in the subject matter through the Deliberative Dialogue forums.*

Form II
Buck Institute for Education (2018) shared the findings in implementing the *project-based learning* (PBL) approach, also known as challenge-based learning which is to design, assess, and manage projects that engage and motivate students.

Learning in a collaborative manner has become a preeminent way of teaching and learning in the past decade. Therefore, an appropriate assessment method plays an important role of improving teaching and learning. One constructive criticism is to emphasize growth and encourage improvement by asking the participants to critique the contents with the statements starting with "I like that…; I wonder if…; and I suggest…" (Hernandez, 2016, para. 17). This course adapted the constructive criticism format in seeking feedback from the students.

Form II was designed to include focus group discussions. A total of five groups of five to seven members were formed. Each team decided on a group moderator and note-taker. Groups were allotted 20 minutes to provide their team input. Each group answered the short format of discussions followed by the project-learning based format, and provided a team summary. The team input was then quantified by the researchers to count the key-word frequencies used among teams. The focus group instructions and cues used in Form II were as follows:

Form II: Regarding to the deliberative dialogue forums for this course, please provide your team input using the following cues.
I like……
I wonder …….
I suggest …….

Reliability and Validity
This research adapted two sets of instruments to evaluate the student experiences which included a range data from mastery of professionalism and ethics to critical thinking skills.

One instrument, CAT, adapted from the NSF (2018), was designed to assess the students' critical thinking and reasoning skills by giving them case study scenarios. The instrument was provided by the NSF's CCLI (Course, Curriculum, and Laboratory Improvement). Based on the NSF report "all of the questions are derived from real world situations. Most of the questions require short answer essay responses, and a detailed scoring guide helps ensure good scoring reliability" (para 2).

The other instrument the researchers used, Form II, adapted the project-based learning to the purpose of collecting the students' constructive critique regarding the deliberative dialogue forums.

This survey was an anonymous survey which protected the identification of the students who participated in this study.

4. FINDINGS

4.1. Value of Deliberative Dialogue Through Form I

This study investigated student experiences regarding the deliberative dialogue forums as a teaching strategy in learning professionalism and ethics for IT fields by means of Form I. At the end of this course, there were 20 participants who completed the online Form I survey individually.

The online survey used a scale of 1 to 5 and yielded the following data for each statement:

Statement 1 of the survey: *I appreciated the Deliberative Dialogue forums more than a traditional lecturing method.*

Of all the students who filled out the survey, 75% of the respondents had scores of 4 or 5. The average score of all respondents was 3.9. One implication is that the group who issued lower scores could serve as valuable feedback to faculty regarding improving the deliberative dialogue forums in a more effective manner. This would entail encouraging students who have less appreciation for the method to understand the value of the method and how it might serve them.

Statement 2 of the survey: *I have gained a good learning experience in comprehending the ethic theories through the Deliberative Dialogue forums.*

Of all the students who filled out the survey, 80% of the students responded with scores of 4 or 5. The average score of all respondents was 4.15. These responses firmly recognize that the deliberative dialogue forum was worthy for the faculty to prepare for many current case studies in order to achieve the learning outcomes of the course.

Statement 3 of the survey: *This Deliberative Dialogue forum improves my critical thinking skills.*

Of all the students who filled out the survey, 80% of the students responded with score of 4 or 5. The average score of all respondents was 4.25. These responses also explained the positive outcomes received from the students' final CAT results.

Statement 4 of the survey*: I have learned to accept and understand diverse views and points.*

Of all the students who filled out the survey, 80% of the students responded with score of 4 or 5. The average score of all respondents was 4.45. This response encourages higher education institutions and faculty to use the deliberative dialogue forums to encourage more students to accept diverse perspectives and viewpoints.

Statement 5 of the survey: *I have gained self-confident in public speaking and improved self-esteem in the subject matters through the Deliberative Dialogue forums.*

Of all the students who filled out the survey, 75% of the students responded with score of 4 or 5. The average score of all respondents was 4.10. This response provided a positive feedback regarding introducing students to the professional and ethical issues they will face when they leave the relatively free and open collegiate environment to enter the workforce where ethical issues and professional etiquette are a daily concern.

4.2. Evaluation of Deliberative Dialogue Through Form II

For Form II, the students formed into five groups made up of five to seven members per group. A total of 25 students participated in discussing and completing the following cues and providing critique regarding the dialogue forums.

Form II: Regarding the Deliberative Dialogue forums for this course, please provide your team input for the following items.
I like……
I wonder …….
I suggest …….

4.2.1. Forum II- Cue: *I Like*

Regarding the Deliberative Dialogue forums for this course, please provide your team input for the following items.
I like……

The key words from the team input regarding "I like….." were quantified based on the categories including *Group Interaction* (N=7), *Diversity Acceptance* (N=2), *Out of Comfort Zone* (N=4), *Class Format* (N=4), and *Engaging Learners* (N=4).

The findings for each category are listed as follows:

Group Interaction
The students expressed that they liked working as a group to review and analyze the case studies. The students had opportunities to interact with different teammates. Since students kept their name tags on for an entire semester, they were able to get to know and interact with newer members every class. Moreover, through group interactions, the students improved their teamwork skills.

Diversity Acceptance
The students learned how to hear opposing viewpoints and understand different people's perspectives related to real life problems.

Out of Comfort Zone
The students liked to be challenged in practicing their public speaking skills which forced them to interact with others, and pushed them out of their comfort zones.

Class Format
The students liked the overall format of the entire course as it offered flexible arrangements for case-study reporting timelines and homework. In addition, the students mentioned that they liked that the instructor tried this new format of learning professionalism and ethics.

Engaging Learners
The students expressed their appreciation in engaging more by applying real world cases on ethics, and indicated that they learned a lot of new ideas from others.

Based on the instructor's observation, all of the aforementioned categories indicated that students were able to achieve their learning outcomes and master professionalism and ethics.

4.2.2. Forum II- Cue: *I Wonder*
The key words from the team input of "I wonder….." were quantified based on the categories of *Other Classes* (N=3), *Case Studies* (N=1), *Lecture Format* (N=1), and *Real Life* (N=1).

The findings for each category are listed as follows:

Other Classes
The students were inquisitive regarding how other classes tackled the deliberative dialogue forums. Students also wondered whether the students in other classes would be more accepting of this method when it came to learning course content.

Case Studies
The students also wondered whether they could have more of a variety in the case studies used. The students indicated that they could learn more about other cases from different teams when they reported the team solutions. The instructor deemed it would only be applicable if there were well-formed databases including real-life case studies covering various topics on professionalism and ethics.

Lecture Format
The students also wondered what this class would be like in a lecture format. The interactions included comments related to how easy it would be to imagine the outcomes of a typical lecturing format covering ethics theories, social responsibilities, regulations, and other theory-based topics. The comments included realistic views on how most computer science students would function in a typical lecture setting on ethics. Most agreed it would lend many to have their heads down working on their laptops or cell phones.

Real Life
The students wondered whether this course actually prepared them for real world/life after college. A follow-up with a phenomenological design covering the period a few years after the students' graduation would offer meaningful results regarding this category.

4.2.3. Forum II- Cue: *I suggest*
The key words from the team input of "I suggest….." were quantified based on the categories of *Time* (N=5), *Case* (N=3), and *Assignments* (N=4).

Time
The students suggested more time for discussions, finding resources, interviewing, and presenting. A 90 minute-class time included a class format comprised of a 30-minute lecture, a 40- minute discussion, and a 20 minute-presentation. Some groups suggested having one class time covering lectures, and one class time conducting deliberative forums.

Case
The students suggested that the case studies could be expanded for more discussions and presentations. Also, more diverse topics and relevant case studies were suggested as part of group discussions and presentations.

Assignments
The students suggested specific key words for discussions and the CAT assessments. One group even suggested omitting CAT assessments. However, due to the pre-and post- comparison, the CAT assessments proved to be valuable in assessing student critical thinking skill growth.

4.3. Critical-Thinking Skills Assessment
The CAT was administered throughout the semester. Two additional CAT assessments based on the teaching topics and learning objectives of the course were designed in a similar way of pre-CAT and post-CAT assessments.

Pre-CAT
The pre-CAT scoring is designed to analyze the following categories (See Appendix A).

1. Were Nokia's leaders acting ethically when they moved their facilities from Germany to Romania and from Romania to Asia which was based on a business decision to reduce costs and improve profits? What ethical theories could apply to this case? Agree or disagree, please explain the reason/s and related theories. (0 - 2 points)

Scoring Point 0: No confirmation stating "agree" or "disagree."
Scoring Point 1: Apply one reason with one related theory.
Scoring Point 2: Apply more than 2 reasons with related theories.

2. What kind of responsibilities does the Nokia's leaders have regarding to the issues in the past years? (0 - 5 points)

Scoring Point 0: None of corporate social responsibilities (CSR) were introduced.
Scoring Point 1: Apply one CSR with applied approaches/theories.
Scoring Point 2: Apply two CSR with applied approaches/theories.
Scoring Point 3: Apply three CSR with applied approaches/theories.
Scoring Point 4: Apply four CSR with applied approaches/theories.
Scoring Point 5: Apply five CSR with applied approaches/theories.
3. Can the organization leaders correct their business pattern of not focusing on customers' needs? How difficult is it to ensure ethical decision making in a business that is organized as a "network of equals"? How does this impact accountability? Provide the ethical considerations in decision-making. Appropriate ethical framework should be included.

Step 1. Develop Problem Statement (0 - 1 point)
Score Point 0: Missing well-defined problem statement.
Score Point 1: Well-defined problem statement.

Step 2. Identify Alternatives (0 - 3 points)
Score Point 0: No alternative was presented.
Score Point 1: One alternative was presented.
Score Point 2: Two alternatives were presented.
Score Point 3: More than two alternatives were presented.

Step 3. Evaluate and Choose an Alternative (0- 3 points)
Score Point 0: No alternative with evaluation was presented.
Score Point 1: One alternative with detailed evaluation was presented.
Score Point 2: Two alternatives with detailed evaluation were presented.
Score Point 3: More than two alternatives with detailed evaluation were presented.

Step 4. Implement Decision (0 - 2 points)
Score Point 0: No recommended implementation procedure was presented.
Score Point 1: The implement plan was presented, but without introducing the procedure.
Score Point 2: The implement plan and procedure were presented.

Step 5. Evaluation Results (Provide the possible outcomes from your analysis.) (0-2 points)
Score Point 0: No predicted results and evaluation for the implementation was presented.
Score Point 1: The predicted result(s) was/were presented, but missing the evaluation for the implementation.
Score Point 2: The predicted results and evaluation for the implementation were presented.

Post-CAT
The post-CAT scoring is designed to analyze the following categories (See Appendix B).

Disregarding how many awards and praises Tribeka Ltd. received in the past, as a project manager, please use the 5 steps of ethics decision-making process to list the possible catastrophes and propose an alternative of overcoming the identified catastrophes.

Critical Thinking Skill (Scoring Sheet)

1. *Agree or disagree with the company's future direction, please explain the reason(s) and related theories. (0 - 2 points)*

The scoring point system used was the same as the Pre-CAT scoring mentioned above.

2. *What kind of responsibilities do company leaders have regarding possible catastrophes? (0 - 5 points)*

The scoring point system used was the same as the Pre-CAT scoring mentioned above.

3. Provide the ethical considerations in decision-making. Appropriate ethical framework should be included.
I. Develop Problem Statement (0 - 1 point)
II. Identify Alternatives (0 - 3 points)
III. Evaluate and Choose An Alternative (0- 3 points)
IV. Implement Decision (0 - 2 points)
V. Evaluation Results (Provide the possible outcomes from your analysis.) (0-2 points)

The scoring point system used was the same as the Pre-CAT scoring mentioned above.

The original CAT assessment point system was converted to a 100-point scale. The students' average CAT assessment grades improved from 67.03 to 74.34. These assessment scores indicated that there was a significant improvement regarding students gradually grasping the importance of applying knowledge from what they have discussed in the deliberative dialogue forums into their decision-making process.

In addition, the findings related to pre-CAT and post-CAT comparison results were as follows. The pre-CAT exam average score was 12.83 (N=27) from a possible score of 18 points. Overall, the students were not able to communicate their creative alternatives with references and support. Moreover, the key terms of professionalism and ethics were not presented, although the exam was a take-home online research exam. At the end of this course, the post-CAT exam average score was 15.61 (N=29) from a possible 18 points. The results showed that more students applied knowledge of social responsibilities and theories of ethics to practice on the professional decision-making process. The chart below showed that the number of students who earned less than seven points dropped from eight to five. More students earned 11, 12, and 14 points from the post-CAT results (see Figure 1).

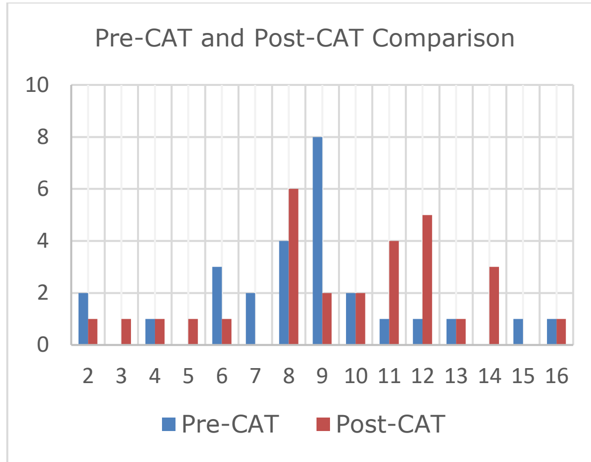

Figure 1. Pre- and Post-CAT Comparison

5. CONCLUSIONS

This research showed that 75% to 80% of the Computer Science senior students in their *Professionalism and Ethics* course evaluations (five-point system) provided high points concerning the implementation of deliberative dialogue forums.

In addition, critical thinking skills of students were improved significantly through the practices of case-study and deliberative dialogue forums.

This research was based on 32 enrolled students in a 58-seat classroom. When the class began, the noise level of group participation was high. Each group was engaged in sharing their input. The vibrant discussions, the focus of the students' eye contact, and friendly approaches were observed during the deliberative dialogue time. If this teaching format were applied to a larger class, a bigger classroom would be needed to allow the instructor to walk around the groups and have enough space as to prevent the noise from disrupting neighboring groups.

Based on the size of the class, each student (moderator) had three rotations to lead the small group. Each rotation was designed to have the moderator present the group discussion in different format, such as a written report, verbal presentation, and digital presentation through various technology. The moderator's verbal and digital presentations were graded by peers. But the written report was graded by the instructor.

The main value of this moderating rotation was that the group members were required to participate in the dialogue and follow up with reference support. Therefore, each member fulfilled their duties to support the designated moderator role. This format also promoted sportsmanship of within the group.

The findings revealed that the students valued the deliberative dialogue forums much more than a traditional lecturing method. Students showed significant improvements in comprehending the ethics theories, in using their critical thinking skills, and in being more receptive to diverse viewpoints. Moreover, this pedagogy increased the students' self-confidence in public-speaking and self-esteem in their subject matters.

However, there are some challenges faculty might consider overcoming when considering using this method. Supporting an innovative teaching method to increase student engagement might affect faculty assessment and evaluation. Deliberative dialogue forums require substantial faculty preparation time prior to each lesson. The students who are skeptical of being exposed to a new approach might resist this method as it requires them to take responsibility for their learning. This challenge is backed up by Thelin (2017) who stated that "college often is characterized as a time and place where students are given both the latitude and obligation to explore and make choices (and mistakes)" (p.86).

Future study would be to continue the research by exploring how a course such as this one could prepare students for the real workforce and life with their improved critical thinking skills and cyber ethical value.

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This paper was selected for inclusion in the journal as an EDSIGCON 2018 Distinguished Paper. The acceptance rate is typically 7% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2018.

APPENDIX A

Pre-CAT: Ethical and Business Setbacks for Nokia (Adapted from Renolds, 2017, p. 32)

I. On the morning of September 5, 2012, Nokia staged a press conference in New York City to announce the official launch of its new Windows 8 smartphones, the Lumia 920 and 820. The event focused heavily on the phone's PureView camera technology. Videos played at the press conference and online emphasized the phone's stabilizing technology. One advertisement in particular extolled the steadiness of the smartphone's camera with a video showing a woman bicycling by a riverbank in Helsinki, supposedly shot on a Lumia 920 by a young man bicycling beside the woman. However, the online tech magazine The Verge decided to take a closer look at the video, and while examining it, a researcher for the magazine noticed a reflection in a window of a trailer behind the woman on the bike. The reflection showed a young man not on a bicycle, but rather in a van – holding a large camera. Further investigation revealed that the shot was taken by a Steadicam, a professional motion picture camera, held by a cameraman in the van. By 4:30 pm. Eastern time, the word was out. And by 8:00 p.m. the same day, Nokia had updated the video with a disclaimer and issued a formal apology.

Five days after the Lumia advertisement fiasco, Nokia announced that it would conduct an ethics review of the incident. "What we understand to date is that it was nobody's intention to mislead, but there was poor judgment in the decision not to use a disclaimer." Nokia spokesperson Susan Sheehan said. She refused to identify the company responsible for producing the advertisement and stated that Nokia would conduct its investigation "quickly, fairly, and privately." The company quickly concluded its investigation, but has not revealed the results of its investigation, other than to acknowledge that "poor judgment" was used. Nor has Nokia not made public any ethics initiative or punitive measures taken as a result of the false advertisement.

II. Nokia announced in 2007 that it was moving production from its facility in Bochum, Germany, to the relatively low-wage environment of Romania. A consumer backlash ensured. The company was eventually required to pay 60 million Euros ($93 million) back to the German state for subsides paid to the company for locating its facilities in Germany. In addition, a boycott was organized by German trade unions, and several cabinet ministers publicly changed to other brands of cell phones. Nokia saw its share of the German smartphone market drop from 70 percent to 50 percent between the factory closure announcements. At the end of 2009, ironically, Nokia's 2011 decision to close the Romanian facility and move manufacturing to Asia met with similar reactions in Romania.

III. In 2008, Nokia Siemens Networks, a joint venture between Nokia and Siemens AG, reportedly provided Iran's monopoly telecom company with technology that allowed it to intercept the Internet communications of its citizens to an unprecedented degree. The technology enables the Iranian government to monitor voice calls, text messaging, instant messages, and Web traffic. Nokia officials insisted that the system constituted "a standard architecture that the world's governments use for lawful intercept" and added that the company had refused to sell the technology to the governments of Burma and China. However, in June 2009, the emerging pro-democracy movement in Iran organized a boycott of Nokia devices and messaging services. Finally, on June 2, 2010, Nokia Siemens Networks held a press conference to apologize for the role its technology played in the brutal crackdown on Iranian demonstrators the year before. In late 2011, Nokia-Siemens Networks announced that it would begin to reduce its business commitments in Iran and would no longer take on any new business with Iranian customers.

The last several years have also been a time of unprecedented financial upheaval for Nokia. Since 2009, Nokia has lost over a third of its revenues, downsized its workforce by about 25 percent, and seen its market capitalization drop by over $100 billion. While the Lumia line of smartphones continues to be the market leader in Europe, Nokia's share of the U.S. market has dropped to less than one percent. The public's response to Nokia's poor ethical decisions has cost the company heavily. The question remains whether Nokia will learn from its current troubles and adapt quickly enough to satisfy its customers, shareholders, and other stakeholders.

Critical Thinking Skill (Scoring Sheet)
1. Were Nokia's leaders acting ethically when they moved their facilities from Germany to Romania and from Romania to Asia which was based on a business decision to reduce costs and improve profits? What ethical theories could apply to this case?
Agree or disagree, please explain the reason/s and related theories. (0 - 2 points)

2. What kind of responsibilities does the Nokia's leaders have regarding to the issues in the past years? (0 - 5 points)

3. Can the organization leaders correct their business pattern of not focusing on customers' needs? How difficult is it to ensure ethical decision making in a business that is organized as a "network of equals"? How does this impact accountability?
Provide the ethical considerations in decision-making. Appropriate ethical framework should be included.

I. Develop Problem Statement (0 - 1 point)
II. Identify Alternatives (0 - 3 points)
III. Evaluate and Choose an Alternative (0- 3 points)
IV. Implement Decision (0 - 2 points)
V. Evaluation Results (Provide the possible outcomes from your analysis.) (0-2 points)

APPENDIX B

Post-CAT (Adapted from online resource)
ttp://www.wipo.int/ipadvantage/en/details.jsp?id=905

The mission of the World Intellectual Property Organization is to promote innovation and creativity for the economic, social, and cultural development of all countries, through a balanced and effective international intellectual property system. You just received a promotion to be the project manager of risk-prevention from any catastrophe in the future. Review the case study below; be familiar with the regulations among intellectual property in the U.S. and internationally; and then propose a plan to prevent any disaster occurred.

Revolutionizing Digital Content Distribution using Patented Technology
http://www.wipo.int/ipadvantage/en/details.jsp?id=905

Disregarding how many awards and praises Tribeka Ltd. received in the past, as a project manager, please use the 5 steps of ethics decision-making process to list the possible catastrophes, and propose an alternative of overcoming the identified catastrophes.

Critical Thinking Skill (Scoring Sheet)
1. Agree or disagree with the company's future direction, please explain the reason/s and related theories. (0 - 2 points)
2. What kind of responsibilities does the company leaders have regarding to the possible catastrophes? (0 - 5 points)
3. Provide the ethical considerations in decision-making. Appropriate ethical framework should be included.

I. Develop Problem Statement (0 - 1 point)
II. Identify Alternatives (0 - 3 points)
III. Evaluate and Choose an Alternative (0- 3 points)
IV. Implement Decision (0 - 2 points)
V. Evaluation Results (provide the possible outcomes from your analysis.) (0-2 points)

Informational Evaluation & Social Comparison: A Winning Pair for Course Discussion Design

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Abstract

Upward and downward social comparison mechanisms may positively affect student performance in course-related work. However, research is not conclusive about whether the negative effects that can also be caused by comparison outweigh the benefits. In this research project, we combined social comparison with detailed informational feedback on a specific performance goal in online discussions. The performance goal was tied to the extent to which student posts and comments exhibited integration of different dimensions of the discussion topic. The social comparison mechanism was based on de-identified discussion transcripts that included the score of each post or comment. Supplemental informational feedback was provided by the instructor in the form of goal-specific annotations on the transcript that clearly explained why each post/comment had received a given score. In this paper, we report on a field experiment that spanned over four semesters, completed in twelve course sections, each involving two online discussions. The treatment courses implemented the 'winning pair' mechanism, which is a combination of informational evaluation and social comparison in online discussion. Comparisons on quality and quantity of student interactions at individual, dyad, and course levels are discussed in detail. We propose that winning-pair could be an effective mechanism advancing quality in creativity-intensive non-mechanical course-related assignments.

Keywords: Online discussion, social comparison, informational evaluation

1. INTRODUCTION

Online discussions are ideal tools for encouraging critical thinking and promoting conversations among peers (Waters & Gasson, 2012). Effective conversations among students in online forums require carefully crafted guidelines, grading rubrics, and feedback (or moderation) by instructors. In the field of information systems (IS), where creative writing is not a core part of the undergraduate curriculum (compared to coding or system design), students must be given explicit performance goals, goal-specific feedback, and opportunities to practice and improve their conversational skills. In this research, students were asked to focus on idea integration. Idea integration indicates that students can identify different dimensions of a discussion topic and are able to make associations among the dimensions (Javadi *et al.* 2013). Different levels of idea integration can be distinguished based on the well-known construct of integrative complexity and measurement thereof (Baker-Brown *et al.*, 1992)

In addition to explaining the specific goals of idea integration, students were given informational feedback on their assigned goal. Students also had access to transcripts of the discussions that included scores and informational feedback for each post and comment.

In summary, this study's treatment included goal-specific guidelines, informational feedback, and a mixed-approach social comparison. The social comparison was mixed (both upward and downward) because students had access to scores of both higher and lower performing peers. The impact of such paired mechanism that is based upon Social Comparison (Festinger, 1954) and Cognitive Evaluation (Deci & Ryan, 1980) theories was examined through field experimentation in twelve information technology course sections.

2. THEORETICAL BACKGROUND AND RESEARCH MODEL

Effective online discussions are interactive and involve both original ideas and responses thereto. To achieve interactivity in online discussions, underpinning group processes must be strengthened. Prior research on group processes has identified factors that contribute to or hinder productivity in group settings. Examples of enabling factors are cognitive stimulation and observational learning; and examples or obstacles are evaluation apprehension and social loafing (Pinsonnault et al., 1999). Evaluation apprehension occurs when fear of being evaluated hinders contributions or creativity. Social loafing occurs when individuals in in a group underperform and their performance matches that of lowest-performing peer in the group. The current study focuses on these two group productivity obstacles by applying Cognitive Evaluation and Social Comparison theories as theoretical lenses (Figure 1) (Deci & Ryan, 1980; Festinger, 1954).

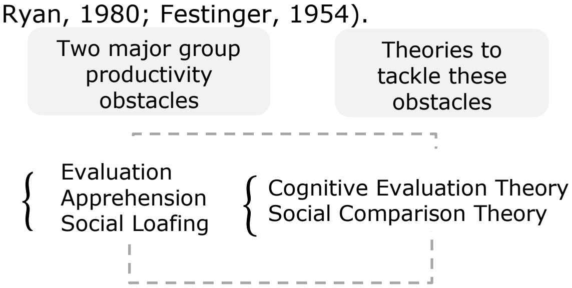

Figure 1: Group productivity obstacles

Social Comparison

Prior research posits that the existence of a discrepancy in a group with respect to opinions or abilities will lead to action by the members of that group to reduce the discrepancy (Festinger, 1954). Social comparison can take many forms and can be implemented through mechanisms, such as charts or leaderboards. Upward or downward social comparison happens when individuals are exposed to the process outcomes of higher and lower performing competitors, respectively. Research indicates that social comparison and its saliency influence outcomes in brainstorming and electronic brainstorming systems (Dugosh & Paulus, 2005). Shepherd and colleagues (1996), for instance, examined the impact of social comparison and the saliency of comparison tools on the brainstorming performance in an electronic setting. In their lab experiments, the authors observed a 63% increase in the number of unique ideas generated in the treatment groups, which used a highly salient social comparison tool. The 63% gain was compared to only a 22% gain in the low salience social comparison treatment group. Dugosh & Paulus (2004) observed higher productivity, as measured by the number of ideas generated, in social comparison treatment; in their experiments, social comparison was manipulated through instructional sets. In another related study, Michinov & Primois (2005) found that social comparison via the use of a shared table showing the contributions of each member positively influenced productivity and creativity; their experimental design allowed communication among brainstormers through a newsgroup feature. The authors noted that even when the brainstormers could publicize their contributions in the newsgroup, the publicizing did not have the same impact as having a highly salient shared contribution-tracking table, i.e., social comparison mechanism.

Informational Evaluations & Goal-Specificity

Individuals are more likely to generate creative ideas when they are intrinsically motivated (Deci

& Ryan, 1980). Intrinsic motivation tends to be higher in experimental groups when individuals expect informational evaluation (Shalley & Perry-Smith, 2001). In scholarly work on teaching and learning, informational evaluation is labeled formative assessment. Research studies on formative assessment suggest that goal specificity is a crucial component of formative evaluation methods (Ambrose et al*.,* 2010). Goal specificity facilitates effectiveness of deliberate practice, which leads to expert-level performance (Ericsson & Charness, 1994). Goal specificity for discussions can be achieved by clearly identifying learning goals on which discussion participants are expected to excel and providing feedback that directly assesses the extent to which students have achieved said goals. Therefore, goal specificity provides a focus for participant's efforts. Goal specificity can be included in assignment instructions and feedback, for example by providing concrete examples of successful performances. This study implemented the winning combination by social comparison based on three elements, namely (1) goal specific instructions, (2) goal-specific feedback on individual as well as peer performances, and (3) concrete examples of successful and unsuccessful performances by sharing scores and feedback on the contributions of all peers.

Integrative Quality

This study uses levels of participation, integrative quality of discussion posts, and the dynamic of interactions among participants as measures of online discussion efficacy. While each student was expected to submit one initial post and four subsequent comments, variations were observed in the levels of students' activities (whether or not they posted an original idea or four comments) and their choices of where to post their comments (in response to whose posts).

In the brainstorming and online discussions literature, most experimental studies have focused on individual idea-sharing behavior in electronic settings (e.g., Wasko & Faraj, 2005). Comparatively little research has been done to examine the extent to which individuals build on the ideas shared by others. This study measures integrative quality of the posts, i.e., the extent to which discussion participants take into account and analyze different dimensions of the topic discussed. An idea is defined as a basic element of thought that consists of at least one testable proposition (Simon, 1947). We conceptualize and measure integrative quality of the posts based on the well-studied concept of integrative complexity in social psychology (Baker-Brown et al., 1992; Suedfeld et al., 1992). More details on the measurements are shared in the section on field experiments.

Social Comparison

The social comparison mechanism in this study was operationalized by allowing and even encouraging discussion participants to view both controlling and informational evaluation that their higher and lower performing peers received on the discussion posts. Controlling (summative) evaluations focus on the outcome, whereas informational (formative) evaluations provide information on how to improve said outcome. Viewing other students' scores and comments associated with those scores implies exposure to both lower performing and higher performing peers, thus yielding a mixed upward/downward social comparison. According to Cognitive Evaluation Theory, individuals are more likely to generate creative ideas when they are intrinsically motivated (Deci & Ryan, 1980); and this study proposed that intrinsic motivation can be higher in experimental groups in which individuals view and process informational evaluation associated with their scores and those of others (Shalley & Perry-Smith, 2001). As summarized in Figure 2, we propose:

Proposition: Social comparision accompanied by informational evaluation is associated with higher quality of integrative ideas.

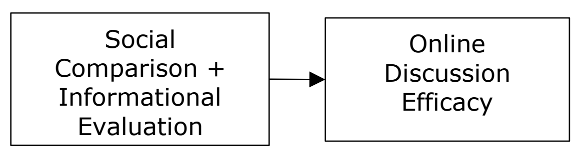

Figure 2: Research model

4. FIELD EXPERIMENTS

The field experiments involved twelve course sections, with three sections each taught during four semesters. Each course section included two discussions, i.e., twenty-four discussions total.

Table 1: Control and treatment group sizes

Condition	Semester	Section sizes	Total Sample
Control	Fall 2014	30, 22, 21	138
	Spring 2015	24, 20, 21	
Treatment	Fall 2015	30, 25, 18	136
	Spring 2016	30, 22, 11	

Half of the course sections were used as control groups (C) and the other half as treatment groups (T). Table 1 indicates the sample sizes for each section.

In the control sections, after the first discussion, students were given their individual scores, and were reminded of the general scoring rubric. In the treatment sections, students were given goal-specific instructions. Goal specific instructions were posted on the course's learning management system and were reiterated in the class by the instructor. An excerpt from the instruction is included below:

"… *your goal is to generate synthetic ideas. It is vitally important for the purpose of this assignment that you generate ideas that synthesize your ideas and those that you read. I expect you to prepare analyses that combine your ideas with ideas presented in the articles that I listed or other articles that you read during your independent research. Your posts will be carefully reviewed for their SAD (systems analysis and design) content and synthetic quality*…"

In addition, after the first discussions, students were given an annotated transcript of the whole discussion, which contained each student's discussion score along with the instructor's goal-specific feedback associated thereto. To alleviate privacy concerns, students' names were removed from the transcripts; and at the time discussion transcripts with feedback were released to students, the online discussion forums were closed for viewing. Both instructions and informational evaluation for the treatment groups were goal-specific in that students were clearly instructed to focus on integrating ideas and were given feedback on the annotated transcript on how they performed with respect to that goal. Following guidelines created by Shalley and Perry-Smith (2001) in their research study on creativity, the instructions were formulated as below:

"…you will be told how your discussion post compared to other students' posts. A transcript of all students' posts & comments annotated with scores and comments for each score was shared with students after each discussion."

To measure the quality of posts, we modified the integrative complexity measure developed by Baker-Brown and colleagues (1992). The integrative complexity measure is a 0-5 scale which rates comments that show "no conceptual differentiation or integration" as 1; and comments in which "the nature of the relationship or connectedness between alternatives are clearly delineated and are described in reasonable detail" as 5. In this study's measurement scale, integrative complexity measurement scores 1-5 were used to represent different levels of integration from non-existent to emergent to fully developed. Examples of comments given to students are included in Table 2. One instructor taught all the sections involved in this study and two trained students coded the discussion transcripts. The inter-coder reliability was high at an average level of .87.

Table 2: Scores and sample feedback

Discussion topic: Project Manager and Business System Analyst roles, collaborate or combine?	
Score	**Sample Feedback**
0	*'I agree' or 'I like' do not contribute the discussion.*
1	*The post includes only acknowledgements; and repeats ideas in the paper.*
2	*The post includes mostly acknowledgements; new ideas or perspectives are emerging but not well developed.*
3	*A valid point on contingencies, but post focuses on summarizing/repeating ideas in the paper rather than presenting a rationale for the given point.*
4	*There is a good point on small vs. large organizations but needed more elaboration, remove the last statement which is unclear and avoid repetitions.*
5	*New ideas, well connected and sufficient reasoning.*

5. DATA ANALYSIS

Discussion networks were created based on binary discussion matrices in which cell (i, j) was 1 if student i commented on student *j*'s posts, and 0 otherwise. Non-binary discussion matrices stored in cell (i, j) the score that student *i* received for the comment posted on student *j*'s post. In the following analyses, both binary and score matrices are used.

The first comparison was conducted on the density of interactions among students in the online discussion forum. Density measures the number of connections among nodes in a given network. For a binary directed network density is calculated by number of ties divided by $n \times (n-1), i.e.$ all possible (directed) ties. For a score matrix, density is the average value of all cells (Borgatti et al., 2002). Denser discussion networks include a higher number of comments between students, and less dense discussion networks include a smaller number of comments. While the discussions expected students to post one original idea and four comments, not all students completed the requirements of the discussion; therefore, variations exist in the density levels of twenty-four discussion networks. Two relatively consistent patterns were observed in the control and treatment sections (Figure 3 in Appendix). All of the control groups, in which students only received their own scores, showed a decrease in density from the first to the second discussion, implying that there might be an evaluation apprehension mechanism in play when students receive only their scores. Evaluation apprehension occurs when students' perceptions on how their contributions is to be scored adversely impacts their motivation to contribute or create high quality contributions. In contrast, the density of all sections in the treatment groups increased from the first to the second discussion. The rates of change in density levels, measured as $\frac{Density_{D2} - Density_{D1}}{Density_{\,D1}}$, are listed in Table 3 for each of the six groups.

Table 3. Changes of Discussion Network Density

Condi-tion	**Semest-er**	**Density change rate**		
Contr-ol	Fall 2014	-25.7%	-27.0%	-18.0%
	Spring 2015	-34.3%	-33.2%	-40.5%
Treat-ment	Fall 2015	23.2%	17.3%	18.6%
	Spring 2016	17.1%	25.1%	18.0%

Next, we examined changes of in-degree centralization of each course section's discussion network normalized over the changes in density (Table 4 in Appendix). At the node-level, the in-degree measure shows the number of comments that each student received. At the class-level, the in-degree measure shows the extent to which the total number of comments exchanged in the discussion are distributed among different posts by different students. For a given binary network, the network–level in-degree centralization measure is the sum of $\sum max_{in-degree} - actual_{in-degree}$ divided by the maximum value possible (Borgatti et al., 2002). A more centralized discussion indicates that a few students receive the bulk of the comments and a less centralized discussion implies that the comments are more evenly distributed among different posts in the discussion. Class-level in-degree centralization measures were normalized by density in order to eliminate the impact of variations in activity levels of each specific cohort. The numbers listed in Appendix Table 4 show the change in centrality assuming equal levels of activity across sections.

Comparison of means with T-test was performed for the normalized in-degree centralization and resulted in a P-value of <0.001. Results shown in tables 3 and 4 indicate a more desired online interaction dynamic observed in the treatment groups: students are more active (higher density) and discussion comments are more broadly distributed (instead of having a few students receiving more attention). It is important to note that while five contributions were expected, students ultimately chose how many contributions they made. Students also chose whose posts they commented on. Thus, variations are observed in both density and in-degree centralization.

After examining density and centralization, we investigated reciprocity. A desired tendency in discussion networks is a low level of reciprocity, which implies that students do not necessarily comment on their peers who have commented on their post, but instead focus on the content of a given post and choose which one to comment on. Reciprocity may be impacted by factors external to the discussion dynamics, such as students' familiarity with each other, as well as internal factors, such as the timing of posts. While in this specific research project we did not measure familiarity at the class- or dyad-level, the second confounding factor is not present due to the set-up of the discussions that separated the posting of original ideas and responding comments. The rate of change in reciprocity from Discussion 1 to Discussion 2 was calculated as $\frac{Reciprocity_{D2} - Reciprocity_{D1}}{Reciprocity_{D1}}$ for each of the six control and six treatment discussion networks. The rates of change in reciprocity were normalized by density to account for variations in level of participation in each cohort. Then the six normalized values were compared with a T-test (Table 5).

Table 5. Comparison of differences in group-level reciprocity normalized by density from D1-D2

Condition	**Mean**	**Variance**
Control	.902	0.566
Treatment	-0.371	0.11
***t-stat*: 3.795 (*df*=10) *p-value*: 0.003**		

The final network-level analysis that we performed examined the extent to which students who interact with each other also comment on other posts together. Such dynamic can be assessed with a clustering coefficient or by using small-world indices (Humphries & Gurney 2008), the latter of is reported in Figure 4.

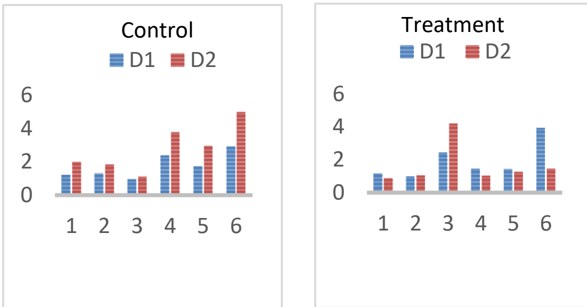

Figure 4: Small-world index trends from Discussion 1 to Discussion 2

An increasing trend was observed in the control groups and a decreasing (except for one value) trend was observed in the treatment groups.

Higher small-word indices imply high levels of clustering coefficient compared to random networks. For a course's online discussions, dynamics that resemble random networks are more desirable than clustering dynamics. The decreasing trend in small-word indices from discussion 1 to discussion 2 in treatment groups indicates that the treatment alleviated the clustering dynamics that may exists among students in the classroom.

In the next step of the analysis, trends of quality improvement were examined in all twelve course sections. To begin, normalized (min-max) averages of scores that each student received on their posts and comments were calculated for each discussion. Then those normalized averages were compared between the two discussions in each experimental course section. A binary vector of quality improvement was created and set to 1 for student i if student i made progress from discussion 1 to discussion 2 and 0 if they did not make any progress. This vector was compared with normalized in-degree vectors later but at this time, the percentage of students who improved was compared between control and treatment groups. The summary of these analyses is included in Table 6.

Because the normalized quality scores were used, a T-test with equal variances was performed to compare percentages of students who improved their normalized average scores from discussion 1 to discussion 2.

Table 6. Percentages of students who improved their normalized average quality from D1 to D2

Condition	Semester	Percentages of students with improved quality		
Control	Fall 2014	60%	50%	62%
	Spring 2015	0.08%	0.2%	0.04%
Treatment	Fall 2015	47%	84%	22%
	Spring 2016	40%	82%	55%
t-stat: **-1.44 (*df*=10)**		***p-value:*** **0.09**		

After that, the binary quality improvement vectors (1: quality improvement; 0: no quality improvement) for each section were compared to binary normalized in-degree improvements for said sections. The binary normalized degree improvement vector had 1 for student i if student i's centrality measure in discussion 2 was higher than their centrality measure in discussion 1 and 0 if the opposite was true. The two vectors were then compared by calculating *Jaccard's coefficient.* Jaccard's coefficient for each course section is listed in Table 7. The insight here is that students' 'flocking' behavior correlates more with the quality of the posts rather than extraneous factors such as friendship or familiarity. This implies that paired mechanisms of social comparison and informational evaluation have helped with alleviating undesirable influence of underlying informal networks in a class on dynamics of discussion, a phenomenon that can adversely influence impartial and constructive conversation among students.

Table 7. Jaccard's coefficient between quality and n-degree improvement vectors

Condition	Semester	Jaccard's coefficient		
Control	Fall 2014	.25	.438	.313
	Spring 2015	0	1	.25
Treatment	Fall 2015	.435	.348	0
	Spring 2016	.105	.421	.429
t-stat: **+2.12 (*df*=10)**		***p-value: 0.06***		

Next, quality matrices were used. In the non-binary quality matrices, cell (i, j) indicates the score (0-5) that student i received for the comment posted on student j's idea, if such comment exists, and cell (i,j) indicates zero if such comment does not exist. Comments that do not convey any useful information will also be given 0 (Table 2). To compare quality improvements from Discussion 1 to Discussion 2 in the control and treatment groups, we calculated the average score for each student across all posts. Then the average scores were normalized in each section, and the normalized average quality of posts was compared for the two discussions in each section to calculate a measure called Integration Improvement Factor (IIF):

$$\text{Normalized scores } NS \text{ in section } s = \frac{score - Min_{scores\ in\ s}}{Max_{scores\ in\ s} - Min_{scores\ in\ s}}$$

$$\text{Integration Improvement Factor } (IIF) = \frac{NS_{D2} - NS_{D1}}{NS_{D1}}$$

Each course section had one *IIF* vector (one vector element for each student), and twelve integration improvement factors for all sections. The sections in fall 2014 and spring 2015 did not apply social comparison (C: control) groups, whereas the sections in fall 2015 and spring 2016 did employ paired social comparison and informational evaluation (T: treatment) groups in the experiment. The *IIF* vectors for the six sections in the control group were concatenated to create IFF_C. Similarly, the IIF vectors for the six sections in the treatment group were concatenated to create IFF_T. A *t*-test was performed to compare the mean value of each. The summary is included below (Table 9).

Table 8. Quality comparisons

Treatment	N	Mean	Variance
Control	139	.14	1.83
Treatment	136	.36	1.46
***t-stat*: -1.4 (*df*=271)**		***p-value*: 0.08**	

Node-level analyses were performed to assess the extent to which each student's improvement in the discussion posts quality was correlated with their structural measures in their discussions' interaction network (e.g., in-degree, reciprocity) and if the level of correlation was different for control and treatment groups. The IIFs calculated previously were correlated with normalized student-level (node-level) in-degree centralizations for discussions in treatment groups. All but one of the treatment groups showed a negative correlation implying that the students who received fewer comments were more likely to improve the average quality of the posts and comments they shared in the subsequent discussion. The correlations were negative for only one section of the control group; the correlations are depicted in Figure 5. This implies that a 'winners keep winning' mechanism was prevalent in the control groups; students who received more comments (whose posts received more attention), improved the quality of their posts. An opposite phenomenon is prevalent in the treatment groups, perhaps because of the informative nature of the comments that helped posters of less popular ideas to work harder on improving the quality of their future posts or because informational evaluation has created stimulated upward social comparison in class.

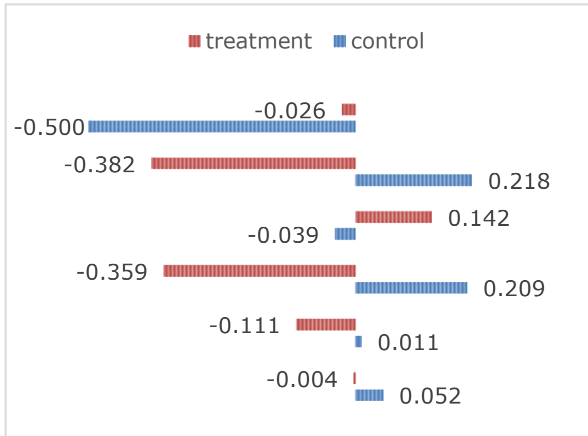

Figure 5: Correlation between quality improvements and normalized in-degree centralization in Discussion 1

The network- and node- level analyses were followed by dyadic analysis. Dyadic analyses would reveal whether or not the interactions at dyad-level persist from discussion 1 to discussion 2. For instance, whether the same pair of students continue to comment on (or ignore) each other's posts. We examined Jaccard's coefficient for similarity between the two discussions' binary networks in each of the 12 sections. We also examined QAP (Quadratic Assignment Procedure) correlations between the two discussions' non-binary networks. QAP helps assess the extent to which patterns observed in a given network are unique observations as opposed to being commonly observed patterns in similar networks. The Jaccard's coefficients and QAP correlation numbers for the six treatment groups were not significantly different from those of the control groups. Therefore, while network-level changes in the discussions were observed, those changes are not discernible at dyadic level when control and treatment groups are compared. In general, a low QAP correlation and Jaccard's coefficient are desirable, they show students treat each discussion independently when it comes to whom they choose to comment on. QAP correlations for control and treatment groups ranged from [.03, .153] to [-.009, 186] respectively; and Jaccard's coefficient ranged from [.087, .155] to [.086, .241].

6. SUMMARY AND CONCLUSION

This study aspires to contribute to the literature on productivity and effectiveness of online discussions by advancing the integrative quality of posts by using a social comparison mechanism accompanied by informational evaluation. The proposed combination of social comparison and informational evaluation included elements of both upward and downward comparisons with goal-specific informational evaluations. The paired mechanisms were used in six of the twelve course sections in the reported field experiments. Treatment groups had higher rates of increase in activity levels (density) from the first to the second discussion (Figure 3 in Appendix), suggesting that the social comparison method accompanied by informational feedback is an enabling factor for students' participation in dialogue with their peers on course-related topics. While the control groups entailed a 'winners keep winning' mechanism, the treatment groups were successful in encouraging students with less popular posts to improve the quality of their second discussion's posts. While causal links have not been examined or established, we believe that the informational nature of the comments has helped posters of less popular ideas to work harder to improve the quality of their future posts and the sharing of classroom posts (scores & feedback) has stimulated upward social comparison in class. Popularity (number of comments received) was a more equally distributed commodity in the treatment groups (using in-centrality measures) when compared to the control groups. Small-world indices were examined to unravel the extent of flocking (co-commenting) behavior among students; a high small-world index would imply that students who comment on each other's posts tend to also comment on a third person post together; small-world index is connected to clustering dynamics which are not desirable patterns in classroom or in online discussions. A lower small-world index would indicate an opener discussion space, one free of external connection patterns (e.g., familiarity). Treatment groups showed a generally decreasing trend in the flocking behavior as shown by the small-world indices (Figure 4). In addition, at class-level, treatment groups showed higher percentages of quality improvement (# of students who improved the average quality of their posts and comments from discussion 1 to discussion 2) and higher levels of quality improvement (the extent of quality improvement) and lower levels of centralization in commenting networks when two consecutive discussions were compared. All these factors contribute to a healthier, more engaging, and open discussion dynamic, thus the findings are consistent with this paper's proposition.

We note that general limitations of field experiments apply to this study as well; we are not certain which students did or did not read the transcript (to actively engage in social comparisons) and how other online and in-class dynamics impacted student commenting behavior in course discussions. The findings of this study, however, are consistent with literature on social comparison and informational evaluation. The paired mechanisms of social comparison and informational evaluation employed in the treatment groups of this study can inform the design of online discussions and electronic brainstorming features, as well as creativity support tools.

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Appendices and Annexures

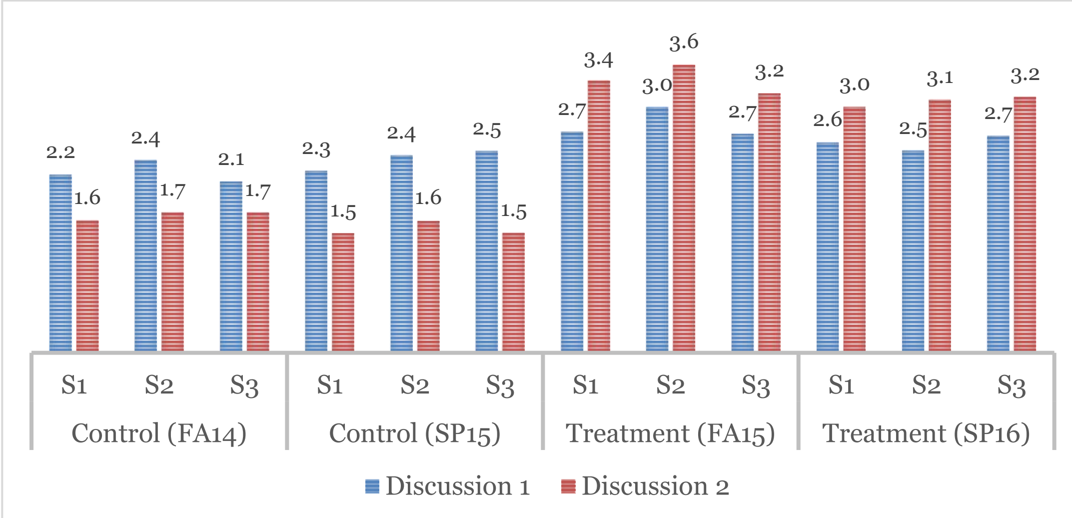

Figure 3: Density in control (left) and treatment (right) groups *

*: The numbers in Appendix Figure 3 were used to calculate the change rates reported in Table 3; because of rounding, the results may be slightly different from those calculated manually.

Table 4. Normalized in-degree measures

Condition	Semester	In-degree centrality change rate normalized by density change			*t*-test comparison
Control	Fall 2014	0.10	0.11	0.09	Mean: 0.11 Variance: .00037
	Spring 2015	0.14	0.13	0.11	
Treatment	Fall 2015	0.02	0.04	0.05	Mean: .047 Variance: .00027
	Spring 2016	0.04	0.07	0.06	
t-statistic: 6.43 (*df*=10) *p-value*: <0.001					

Simulation for Network Education: Transferring Networking Skills Between Simulated to Physical Environments

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Abstract

Simulated environments can provide a convenient, effective way to teach skills. Simulations have been used for decades to teach skills such as piloting aircraft. As technology has improved, it has become feasible to simulate many other tasks. Recent advances in virtual and augmented reality provide new avenues for expanding training using simulations. Going forward, it is imperative that we understand how skills are transferred from simulated environments to physical environments. The current research investigated network simulation training in an introductory computer networking course. Students completed networking exercises in a simulated network environment using Cisco Packet Tracer then subsequently completed exercises using physical Cisco routers and switches. Data from the study indicates that simulations are effective tools to teach computer networking principles but may not necessarily eliminate the need for students to learn using physical networking equipment. Student perceptions of simulation realism explained a large portion of the variance in skill transference between the simulated and physical environments. Practical advice for instructors teaching networking using simulated and physical environments is given.

Keywords: Simulation, Computer networking, Pedagogy, Training

1. INTRODUCTION

The demand for computer networks continues to grow. High speed internet, Wi-Fi, and mobile network deployments continue to extend internet access globally. Businesses use networks to improve operations, increase employee productivity, and create novel applications. For example, Amazon required a high-speed, stable wireless network to enable its Kiva autonomous robots to automate warehouse operations (Li & Liu, 2016). Ironically, cloud computing increases the importance of networking rather than reducing it, as the network provides critical access to the leased infrastructure in the cloud. Educators must teach computer networking skills effectively so that students can enter the workforce ready to deliver networking solutions that businesses expect and to develop innovative systems, even in a cloud-first environment.

Networks are complex systems with many elements that are difficult to directly observe. While professionals can use signal strength bars, blinking lights on a switch, and other status indicators as gross indicators of network functionality, much of the network operation goes unseen. Simulations may be a way to increase understanding of what occurs in a computer network.

Simulations enhance learning environments. Virtual representations of the complex world allow educators to give learners experience that should transfer directly to the physical world. Many organizations are exploring how simulations can improve training delivery for continuing education in the workforce (Bell & Kozlowski, 2008). Results of simulation training are encouraging. Training with game simulations has demonstrated improved declarative knowledge, procedural knowledge, retention and self-efficacy (Sitzmann, 2011). But are simulations a silver bullet? Careful consideration of pedagogical factors and simulation design must be given to ensure that simulation training is effective.

Many fields have used simulations effectively for education. Pilots have used sophisticated simulations for decades. Doctors have used simulations to learn skills used in surgeries. In the computer world, software simulations allow information technology students to learn hardware and software platforms in an isolated learning environment.

Cisco Systems developed Packet Tracer, a visual network simulation tool that helps networking students and professionals learn networking fundamentals, design networks, and troubleshoot network configurations. Using Packet Tracer, students can interact with simulated network hardware without the need for physical routers and switches (Frezzo, Behrens, Mislevy, West, & DiCerbo, 2009).

Many elements of Packet Tracer's simulation match the physical world counterparts. Packet Tracer has models of switches and routers sold by Cisco Systems. Nearly all functionality supported by the physical equipment works in Packet Tracer. However, there are a few key differences. Experience teaching students in Packet Tracer then having them apply their skills using physical equipment proved to be more challenging than expected. This led us to investigate the differences between the physical and simulated environments to determine how the simulated training might be improved.

In the following sections we will address the theoretical background of training in simulations, describe our research methodology, and present our results. We conclude with a discussion of our results as they apply to future research and guidance for educators who use simulations.

2. HISTORY OF SIMULATIONS

At a high level, simulation is the imitation of a real-world process over time (Banks, 2001). Simulations "evoke or replicate substantial aspects of the real world in a fully interactive manner" (Gaba, 2004, p. i2). Researchers have investigated overall effectiveness of simulations for training purposes and found them useful in many contexts. This section discusses some of the key contexts that have driven research in simulations.

Simulated Training Environments

Flight simulators are among the most common simulators in the cultural zeitgeist. One of the first was Edwin Links "Blue Box"—an electric and mechanical replica of an aircraft that could be used to assess pilot proficiency (R. Smith, 2014). Simulation proved to be so helpful that the Federal Aviation Administration would later require commercial pilots to train using simulation to achieve licensure (Rosen, 2008).

Simulations allow medical professionals to practice in an environment that minimizes the cost of mistakes. Patient safety is a key driver of simulations in medical training (Akaike et al., 2012; Datta, Upadhyay, & Jaideep, 2012). Some of the earliest examples of medical simulations include human patients built in clay (Jones, Passos-Neto, & Braghiroli, 2015). Surgical simulation training results in more proficient medical professionals (Dawe et al., 2014). Today, digital simulations using virtual reality augment physical simulations such as mannequins.

Simulations have proven useful in other contexts. The military uses simulations for combat training (R. Smith, 2010). Golfers can improve their game with indoor simulations (Libkuman, Otani, & Steger, 2002). Mine operators use simulations to improve safety outcomes(Van Wyk & De Villiers, 2009). Games, such as the *Oregon Trail* (developed by MECC in 1974), simulate American frontier life for educational purposes. Increasingly, simulation games are being used for training in business environments (Sitzmann, 2011). Clearly, simulations can aid training in a variety of fields. In the following section, simulations in a computer networking context are discussed.

Computer Network Simulations
Several classes of network simulations exist. A small distinction exists between simulation and emulation. In a simulation, the user interface is designed to respond in the same way that the physical devices would respond, though the underlying programs and routines might vary. Packet Tracer is a popular network simulator that has been used to teach networking principles and practical skills (Zhang, Liang, & Ma, 2012).

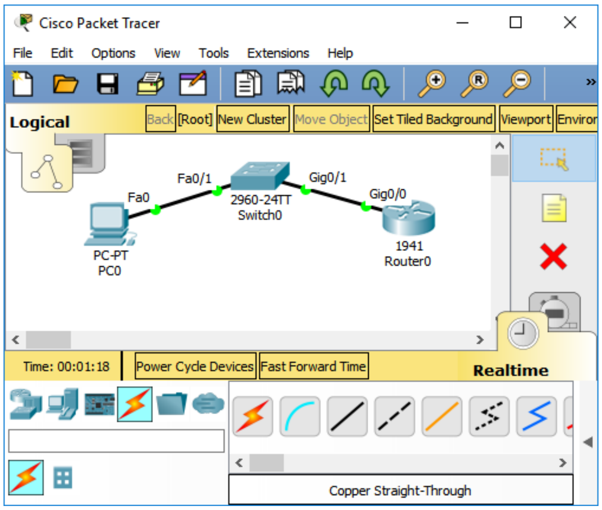

Figure 2: Small Network in Packet Tracer

In an emulated environment, the software runs the actual firmware and code that runs in the physical environment. GNS3 is a network emulation tool that works similarly to simulations (Gil et al., 2014). From an end user perspective, emulation and simulation can appear to be identical (aside from increased resource utilization typically required by emulation). Network simulations may enable distributed groups to collaborate in a semi-synchronous manner (A. Smith & Bluck, 2010).

Network simulations can vary widely in their graphical representation. Whereas Packet Tracer and GNS3 largely target educators and learners they feature graphical user interfaces that lower the learning curve. In contrast, products like DeterLab enable the creation of complex network topologies using the Network Simulator language syntax (Mirkovic & Benzel, 2012). In Packet Tracer, a network switch is a graphical icon on a visual workspace. In DeterLab, a network switch is a line of text in a configuration file.

Teaching with Simulations
A primary benefit of training with simulation is that simulations typically use an active learning model. Active learning activities require students to do things and think about what they are doing (Bonwell & Eison, 1991). Frequently, simulation exercises are goal oriented, such that the learner must take active action and progress through a series of steps to attain the goal. Active learning is more effective than noninteractive approaches because it requires the learner to be more cognitively engaged (Sitzmann, Kraiger, Stewart, & Wisher, 2006).

A meta-analysis of simulation training shows that the interactive nature of simulations leads to improved cognitive gains compared to traditional instructional techniques (Vogel et al., 2006). It should be noted that interactivity is a feature that must be built into simulation training. For example, in one training simulation, participants navigated a virtual world and interacted with different characters and items in the world, but all learning was passive through reading text such as digital books or transcripts (DeRouin-Jessen, 2008). Examples of active learning through simulation include an exercise in which learners used simulators to interactively build electronic circuits (Zacharia, 2007).

Pazil et al. (2007) identified four key elements of simulation exercises: exposure, sequence, feedback, and repetition. In the exposure phase, learners are introduced to the scenario and given learning objectives. In the sequence phase, learners are walked through the exercise, typically with increasing difficulty as the exercise progresses. In the feedback phase, the instructor and learner work together to assess performance. Debriefing at the conclusion of the simulation exercises is critical to give learners time to reflect on learning objectives (Cho, 2015). This reflection should help learners understand how the exercise will apply in future work (Kaufman, 2003). Repetition allows learners to solidify skills and correct mistakes.

It is critical that skills learned in simulations are retained when applied to real-world scenarios. One way in which this transfer occurs is when new knowledge and skills can be applied to work in daily life (Simons, 1999). One barrier to transference is the difficulty in recognizing situations where the knowledge and skills can be applied (Bereiter, 1995). Cold Stone Creamery provided a game to its employees that aimed to increase productivity and reduce waste (Jana, 2006). Though employees had fun playing the game and shared it with friends, it is not clear if behavior serving ice cream changed. If the differences between simulation and work in daily life are great, it is likely that learners will struggle with skill transfer. This is likely truer with novices rather than experts. Experts are more likely to understand the principles that simulations are teaching and more easily understand how the principles can be applied in new contexts.

Outcome Variables
Measuring simulation training effectiveness is an important consideration because too often simulation developers focus on technology rather than learning (Salas, Bowers, & Rhodenizer, 1998). Commonly measured outcome variables include self-efficacy, declarative knowledge, procedural knowledge, and retention. By improving these outcomes, other important outcome variables can be improved. For example, error rates are a primary concern in medical practice (Leape, 1994). While computer networking professionals rarely deal with life or death scenarios, mistakes can lead to substantial losses in the confidentiality, integrity, and availability of systems. By improving self-efficacy, declarative knowledge, procedural knowledge, and retention, educators can improve many secondary outcome variables.

Self-efficacy is the confidence in which learners feel that they have gained knowledge and can apply their skills (Bandura, 1997). Because simulations provide opportunities to accomplish tasks defined in learning exercises, they can contribute to self-efficacy (Bandura, 1977). Self-efficacy is important, but it should be noted that it is a self-assessment and therefore educators should augment its measurement with other variables.

Declarative knowledge is they retention of facts, principles, and the interrelationship between them (Kraiger, Ford, & Salas, 1993). Procedural knowledge is the knowledge required to successfully carry out a task and is typically learned by doing (Koedinger & Corbett, 2006). In computer networking, the differences between declarative knowledge and procedural knowledge can be stark. Students who learn about networking solely through books and classroom discussions may find themselves unable to apply practical networking skills, such as configuring a router. Retention is the degree to which declarative knowledge is retained after training has been completed, typically measured at least several weeks after the learning exercises.

3. TEACHING COMPUTER NETWORKING WITH SIMULATIONS

Simulations that provide constant feedback help students learn by continually allowing students to assess their performance (Abela, 2009). Network simulation software can provide feedback indicating if configuration changes were made successfully through methods such as error messages, indicator lights on hardware, or successful connectivity between devices.

Simulation-based training differs on its fidelity. Fidelity is composed of many dimensions, such as accuracy, believability, verisimilitude, and realism (Feinstein & Cannon, 2002). High fidelity training closely mimics the real-world physical environment, but these simulations can be costly to produce. There has been a push for creating simulations that emphasize psychological fidelity by evoking the critical learning components that apply to real-world scenarios (Kozlowski & DeShon, 2004). Fidelity can be objectively measured in part by comparing features of a simulation to its real-world counterparts. In the current study, we focus on perceived fidelity. Perceived fidelity can be high if the simulation experience is similar to the real-world experience despite differences between the two environments (Lee, 2017). Of the dimensions that compose fidelity, we focus on realism. Realism is concerned with how closely a simulation represents the real-world environment (Norris, 1986). The nature of training with simulated and physical network devices controls for many other facets of fidelity. Realism is the primary dimension that would differ between environments.

Hypotheses
Based on the review of the literature, we set forth the following hypotheses.

H1: Students participating in a simulated learning environment will increase their computer networking self-efficacy.

We believe that following learning in a simulated environment, students will continue to improve their computer networking skills when subsequently completing exercises in a physical environment. In essence, simulation is only one step in the learning process. We therefore hypothesize:

H2: Students participating in a physical learning environment after using a simulated environment will further adjust their computer networking self-efficacy.

We posit that the most effective learning will have occurred once students complete exercises in both the simulated and physical network environments. Therefore:

H3: The combined effect of simulated and physical training on computer networking self-efficacy will be greater than either method alone.

A key consideration for determining how effectively skills transfer should be the perceived realism of the simulation. If the simulated environment does not match the physical world, it is likely that skills transference will be low. We therefore hypothesize:

H4: Students that perceive simulated environments to be realistic will be more able to transfer their knowledge between the simulation and a physical environment.

4. METHODOLOGY

A mix of qualitative and quantitative methods were used. There has been a call for carrying out mixed methods information systems research (Venkatesh, Brown, & Bala, 2013). Specific to simulation-based training, qualitative methods "are best suited for building an understanding of the processes that drive effective performance in the real world" (Salas, Rosen, Held, & Weissmuller, 2009, p. 353). Quantitative measures were used to analyze specific variables relevant to learning outcomes, attitudes, abilities and other related constructs.

Data was gathered in an introductory networking course in a Midwestern university. The data was gathered during a normally scheduled classroom activity. In total, 17 participants (3 female, 14 male) completed the study.

The networking course was offered in a computer lab equipped with Cisco 1960 switches and Cisco 1941 routers. This equipment matches models available in Packet Tracer. Using the same models in the simulated and physical environment enabled a direct comparison.

Prior to the study, students had been introduced to Cisco Packet Tracer and physical networking switches and routers. All students had completed exercises in both environments. In the qualitative part of the study, students were asked to answer open-ended questions. Validated items were used where possible for the quantitative survey. A complete list of survey items can be found in Appendix A.

The quantitative analysis was a within-subjects quasi-experiment. Because the students completed the exercises simultaneously, it was not possible to observe each error they made or time their results.

In the study, students first reported their computer networking self-efficacy (CNSE). Next, they completed an exercise using Packet Tracer. The exercised included the creation of VLANs on a Cisco 1960 switch, assigning IP addresses to clients and Cisco 1941 router interfaces, setting up OSPF on the router, and other configurations needed for a small network in a single building. After completing the exercise in Packet Tracer, students again assessed their CNSE. Then, students completed the same exercise using physical networking equipment. After completing the exercise, students again assessed their CNSE and completed other survey items as listed in the appendix.

5. RESULTS

This section reports the results from the student surveys. The quantitative data was analyzed using R 3.4.1 (R Core Team, 2013) and SmartPLS 3 (Ringle, Wende, & Becker, 2015). The results of the qualitative surveys were analyzed for trends in response patterns.

Quantitative Data Analysis

Computer networking self-efficacy is important to this study, as it shows students' perceptions of their abilities. Since this study occurs at the end of a semester-long course of study, students are expected to be proficient and to have a realistic understanding of their own abilities and shortcomings. Self-efficacy is measured at three times: before the exercise (Time 1), after completing the exercise in a simulated environment (Time 2), and finally after completing the exercise in a physical environment (Time 3). Students are asked three questions at each time (please see the measure items in the appendix); the scale combines these scores through simple averaging. Descriptive statistics are provided in Table 1.

Time	N	Min	Max	Mean	Standard Deviation
1	17	2.00	7.00	4.79	1.21
2	17	3.33	7.00	5.21	0.91
3	17	3.33	7.00	5.44	0.97

Table 1: Descriptive Statistics for Computer Networking Self-efficacy

These observations will be highly related because students have inherent characteristics that will impact their appraisal of their CNSE, ranging from optimism, actual ability, and personality traits. Thus, high levels of correlation are expected, and seen. As can be seen in the paired samples correlation table (Table 2) below, all three of the correlations are significant at the p = .001 level.

	N	Corr.	Sig.
CNSE Time 1 & CNSE Time 2	17	.893	<.000
CNSE Time 2 & CNSE Time 3	17	.819	<.000
CNSE Time 1 & CNSE Time 3	17	.728	.001

Table 2: Paired Samples Correlations

Hypothesis 1 predicts that students participating in a simulated learning environment will adjust their computer networking self-efficacy from the anchor they set for themselves during the period before completing the exercises. Visual inspection of Table 2 shows that the means are changing; however, to ensure the mean differences are statistically significant, a paired samples T-test is used because the observations are not independent. The paired samples T-test results are provided in Table 3 below.

	M	St.D	t	df	Sig. 2-tailed
CNSE Time 1 - CNSE Time 2	-1.86	2.18	-3.00	16	.008
CNSE Time 2 - CNSE Time 3	-0.53	1.77	-1.23	16	.236
CNSE Time 1 - CNSE Time 3	-2.12	2.55	-3.43	16	.003

Table 3: Paired Samples Test

Support for Hypothesis 1 would require a statistically significant difference between Time 1 and Time 2, which is indeed the case (t=3.00, p=.008). Thus, Hypothesis 1 is supported.

Hypothesis 2 predicts that students will once again adjust their computer networking self-efficacy between times 2 and 3. Using a similar paired samples T-test, this hypothesis does not receive support (t=-1.23, p=.236).

Hypothesis 3 predicts that the combined effect on computer networking self-efficacy will be greater than either of the other adjustments. Said another way, students will change their self-efficacy in only one way. Visual inspection of the means shows that students increased in their self-efficacy over time, even though this was a review activity. For each step, the mean did increase, without any retreating effect.

Hypothesis 4 predicts that students that perceive simulated environments to be realistic will be more able to transfer their knowledge to the physical world. To help us measure the effect and remove measurement error simultaneously, this hypothesis is tested using Partial Least Squares Structural Equations Modeling (PLS-SEM). Because of the small sample size, a simple model must be used to provide enough power to detect any effects. With realism predicting transferability, 44.8% of the variance in transferability was explained by students' perceptions of realism. The standardized path coefficient is 0.669 (t=5.25, p<.001). Thus, Hypothesis 4 is supported.

We further explored the data to discover attitudes about Packet Tracer and the physical equipment. Students reported whether they strongly disagreed (1) or strongly agreed (7) that they were easy to use on a 7-point Likert scale. Packet Tracer was rated as easy to use (M=6.00, SD=0.80). The physical equipment was rated slightly less easy to use (M=5.67, SD=1.00). A paired T-test found no significant difference between the ease of use of Packet Tracer and the physical equipment (t=1.04, p=.31).

The usefulness of Packet Tracer to improve computer networking abilities was likewise measured. There was strong agreement that Packet Tracer was useful (M=6.25, SD=0.67).

Qualitative Data Analysis

Student responses to open ended questions were analyzed for trends in the responses. First, students were asked what differences they found between using Packet Tracer and the physical networking equipment. Several students noted that cabling the equipment differed substantially in the two environments. Students generally found that it was more difficult to make configuration changes to physical equipment than the equipment in Packet Tracer. Several students noted that it was faster to work in Packet Tracer because there was no need to reset the hardware configuration prior to use. Resetting the configuration for physical equipment is necessary to ensure that previous lab exercises did cause configuration conflicts. Differences in cabling were frequently mentioned. With physical equipment, students needed to ensure that power cables were attached—a step not needed when using Packet Tracer. Though the results generally conveyed the idea that exercises were easier in Packet Tracer, one student said, "Packet Tracer sometimes gives you too many options and makes it easy to slip up." Another student remarked, "The most obvious thing I noticed was you are not handling physical equipment. There is something a lot different handling physical equipment than packet tracer. You don't have to physically cable anything in packet tracer like you do with physical equipment."

Students were asked to describe things that make it difficult to apply the skills learned in Packet Tracer to physical networking equipment. Several students mentioned that cabling is easier in Packet Tracer. In Packet Tracer, it is impossible to plug a cable into a port without specifically choosing the port. With physical equipment, some students tended to plug a cable into open ports that did not necessarily match the exercise instructions. Differences in cabling was by far the most common response. It was also more difficult to access the configurations using physical equipment.

Students were asked which parts of Packet Tracer they found most confusing that were unique to Packet Tracer. Few themes were consistent across multiple responses. Finding objects, lack of clear labels on icons, difficulty cabling, and finding ports were all mentioned but not consistently. One surprising comment was that Packet Tracer is "not hands on and makes it more confusing." Several students reported that nothing was confusing about Packet Tracer specifically.

Students were asked, "What parts of the physical Cisco networking equipment do you find most confusing?" The most common response by far were cabling followed by accessing the equipment configuration and command syntax. Having to switch the console cable from the configuring laptop to the network device causes confusion, especially when working with multiple devices.

6. DISCUSSION

In trying to make sense of the results, the non-support of Hypothesis 2 presents a conundrum. From qualitative data, students could tell the difference between the simulated and physical environments. The self-efficacy increases, but there is not enough power to determine that the difference is greater than chance. One possible explanation is that students' confidence increases with each interaction with networking. Simulation is good enough to create a statistically significant difference in students' self-efficacy in this study. While there was another increase in students' computer networking self-efficacy with physical hardware, we could not ensure it was not due to chance. This could be an artifact of the small sample size for this study.

The results support the use of simulations and physical networking equipment to teach computer networking. However, the results cannot be used to unambiguously determine whether computer networking can be taught using either method alone. Our experience teaching networking classes in years prior to the outfitting of a lab with physical networking equipment tells us that physical equipment is important. Network simulations were adopted at our university after the physical equipment. Together, the technologies complement each other very well. Many institutions do not have physical lab spaces, or perhaps teach classes online where physical colocation is not possible. In such cases, network simulation software is likely the primary vehicle for teaching computer networking. Based on our history of teaching with no technology support (physical or simulated), physical, and simulated, we feel that all are necessary. The data in the current study supports the notion that the physical computer networking equipment augments network simulation training. Though the simulated and physical environments may be perceived as similar by an experienced practitioner, novices are likely to be more sensitive to interface differences. We believe that for students to be well prepared to work with computer network equipment, some hands-on experience with physical equipment is invaluable.

7. LIMITATIONS

Time to complete the exercise was not measured because of key differences between the simulated and physical environments. For example, accessing a switch's configuration in Packet Tracer only requires that a learner click on the switch icon in the workspace, and open the command line interface tab. Accessing the same configuration with the physical equipment requires that learners connect a USB adapter, determine the COM port of the USB adapter in the Windows Device Manager, launch PuTTY, enter the connection information in PuTTY and open the connection. Future studies could control for those differences to measure time to completion.

Due to sample size limitation, a within-subjects quasi-experiment was used. In the future, it would be helpful to randomly assign students to SBT or no-SBT conditions prior to the physical exercise to more direct assess the impact of SBT.

8. CONCLUSIONS

Simulations can be a powerful tool for effective computer network training. In the current study, we demonstrated how Packet Tracer can augment physical networking exercises to teach computer networking skills. Data from the study shows that while Packet Tracer does help students perform better when using physical hardware, instructors must work with learners to bridge several key gaps. Learner perceptions of simulation realism were highly correlated with perceived skill transference.

In a report on instructional games, Hays (2005) suggests that games must be part of a larger instructional program. Learners should be aware of simulation exercise learning objectives, otherwise knowledge gained in the exercises can stay there (Tobias & Fletcher, 2007). In the context of computer networking, we believe that network simulations should exist to augment, not replace working with physical networking equipment. Unique benefits to each method exist to support learning.

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Editor's Note:

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Appendices and Annexures

Appendix A – Survey Measures

Qualitative Survey Items

- What differences do you find between the using Packet Tracer and the physical Cisco networking equipment?
- Describe things that make it difficult to apply the skills you learn in Packet Tracer to physical networking equipment.
- What parts of Packet Tracer do you find most confusing that are unique to Packet Tracer (not physical networking equipment)?
- What parts of the physical Cisco networking equipment do you find most confusing?

Quantitative Survey Items

All items were measured on seven-point Liker scales unless otherwise noted, with 1 = strongly disagree and 7 = strongly agree.

Computer Networking Self-efficacy (Adapted from Taylor & Todd, 1995)	In this context, building a network for a small building includes the configuration of client devices, a switch and a router. Switch configuration includes basic security, VLAN creation, and spanning-tree protocol selection. Configuration of the router includes basic security, interface configuration, and OSPF configuration.	
	CNSE1	I feel comfortable creating a network for a small building on my own.
	CNSE2	If I wanted to, I could easily create a network for a small building on my own.
	CNSE3	I can create a computer network for a small building even if no one is around to help me.
Perceive Ease of Use – Packet Tracer (Adapted from Venkatesh & Davis, 1996)	EUPT1	My interaction with Packet Tracer is clear and understandable.
	EUPT2	I find Packet Tracer to be easy to use.
	EUPT3	I find it easy to get Packet Tracer to do what I want it to do.
Perceived Ease of Use – Physical Equipment (Adapted from Venkatesh & Davis, 1996)	EUPE1	My interaction with physical network equipment is clear and understandable.
	EUPE2	I find physical network equipment to be easy to use.
	EUPE3	I find it easy to get physical network equipment to do what I want it to do.
Simulation Realism (Adapted from Feingold, Calaluce, & Kallen, 2004)	SR1	Packet Tracer resembled a real physical network environment.
	SR2	Packet Tracer provided a realistic networking environment.
Perceived Usefulness of SBT (Adapted from Venkatesh & Davis, 1996)	PU1	Using Packet Tracer would improve my performance in learning computer networking.
	PU2	Using Packet Tracer in computer networking would increase my computer networking abilities.

	PU3	Using Packet Tracer would enhance my effectiveness in learning computer networking.
	PU4	I find Packet Tracer would be useful to learn computer networking.
Transferability (Adapted from Feingold et al., 2004)	T	Packet Tracer prepared me for real a real physical networking environment.

What! No GUI? – Teaching A Text Based Command Line Oriented Introduction to Computer Science Course

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Abstract

Computer Science students need to acquire knowledge about both the hardware and software aspects of computing systems. It is necessary for them to understand how each layer interacts with one another. However, since Graphical User Interfaces have become ubiquitous, the opportunities to interact with the computer via a command prompt as part of their course offerings are few and far between. The result has been that an intuitive understanding of this interplay has been lost. This paper describes an Introduction to Computer Science course that utilized the Raspberry Pi Linux based computer in a text based, command line environment for all programming assignments. The students edited their programs using the Nano text editor. They submitted their programming assignments using SFTP. They configured and managed their Raspberry Pis, including installing and configuring the Apache web server, from the command line.

Keywords: Computer Science Education, Introduction to Computer Science, Raspberry Pi, Linux, Pedagogy, Command Line.

1. INTRODUCTION

The Introduction to Computer Science (CS) course (CSIS110) at Siena College is a blend of CS0 and CS1 topics, with an even split between CS concepts and programming. It is a required course for both CS majors and Information Systems minors, as well as for students majoring in Computational Science and Actuarial Science.

In order to attract students with varying interests, several variations of the course, each with its own focus (flavor), have been offered in recent years. The offerings have included flavors in Alice, graphics and games, multimedia, music, and scientific computing, with the last three being offered using the Python programming language. While all of the sections utilize the Dale and Lewis (2013) text and cover the same CS concepts, each of the flavors utilizes a second textbook appropriate to its focus.

Over the years, as operating systems have evolved, we have moved away from using a command line interface, thereby abstracting how a computer operates. As the desktop Graphical User Interface (GUI) became the de facto standard, we have been graduating CS students who, at most, were vaguely aware of the existence of an operating system's command line interface. This runs contrary to the need for CS students to understand how hardware and software layers interact with one another.

Kendon and Stephenson (2016) report the results of a non-credit course that provided hands-on Linux command line instruction. The course covered file management, text editing, piping and redirection, and compiling and running programs. The authors report that the course was well received, and based upon post-instruction surveys, the students found the hands-on labs and learning about the command line to be valuable.

While examining CS faculty's perception of the instructional use of Unix, Doyle and Lister (2007) found that faculty believed that it should be part of the CS curriculum since it allows you to "interact with [the computer] more directly than using something like windows which has a GUI on top of it" (p 21). They also found support for the idea that working at the command line provides a more powerful environment than working in Window's GUI. When reporting on the use of a treasure hunt game to motivate learning Unix, Moy (2011) found that the command line forces students to better understand the task at hand.

The Raspberry Pi is a credit card sized affordable single-board computer developed in the United Kingdom by the Raspberry Pi Foundation, and is capable of running a number of different operating systems, including Debian Linux. The foundation's goal is to put computing power into people's hands "so they are capable of understanding and shaping our increasingly digital world, able to solve the problems that matter to them, and equipped for the jobs of the future" (Raspberry Pi Foundation 2018).

Incorporating hands-on activities in an introductory CS course has been shown to augment a student's understanding of the course material (Wu, Hsu, Lee, Wang & Sun 2014). The Raspberry Pi has been used successfully in providing hands-on instruction in a number of fields, from bioinformatics (Barker, Ferrier, Holland, Mitchell, Plaisier, Ritchie, & Smart 2013) to building a microscope as part of a Life Sciences course (Rajani, Markus, Ward, McLean, Gell, & Self 2017) to Chemistry (Geyer 2014), and Physics (Singh & Hedgeland 2015), as well as in CS (Jaokar 2013; Frydenberg 2017; Black & Green 2017).

Having had some experience with the then new Raspberry Pi, I proposed offering a flavor that focused on Linux for the Fall 2014 semester, providing students with a number of command line, text based labs and homeworks. In order to not inflate the textbook cost for the course, the students purchased their own Raspberry Pi as their second "textbook." Open source and on-line material were used for supplemental readings.

2. BACKGROUND

The primary goal of the Linux flavor was for the students to feel comfortable in a command line environment, which, to the uninitiated, can seem intimidating. Being able to use the command line is often more efficient than point and click; can give the user greater control over the computer, especially when performing administrative functions; allows the user to install programs that may not be available as an application; and can automate repetitive tasks.

The course consisted of two one-hour lectures each week, as well as eleven labs. I created five new labs in order to cover the new topics. Using material from the other existing flavors, I modified three existing labs, such as enhancing the operating systems lab, and reused three of the labs that covered topics, such as exploring object oriented programming using ALICE. Labs were run following the paired programing paradigm (Bevan, Werner, & McDowell 2002; Simon & Hanks 2008).

Knowing that I wanted the students to be able to write programs that generated dynamic web pages via Common Gateway Interface (CGI), I selected Perl (Wall 2000) based on how commonly Perl is used for this purpose. While not currently in vogue as a first programming language, Perl seemed like an obvious choice for teaching programming in a strictly text based environment. In addition, given that Perl has weakly (dynamically) typed variables, the students did not need to worry about declaring variable data types.

Following the Dale and Lewis (2013) text, the course covered a breadth of topics. One topic was data representation: binary, octal, hexadecimal, signed magnitude, text compression, colors, images, and audio. Another topic included Boolean expressions, gates, truth tables, and circuits. The computing components topic covered how to calculate disc seek, latency, and transfer times, and von Neumann architecture, which serves as an introduction for assembly and machine language. It also touched on concepts from operating systems, programming languages, and artificial intelligence. While required for CS majors and minors, a wide spectrum of students enroll in CSIS110 since the course can be used to fulfill the college's quantitative analysis graduation requirement.

The students' Perl code needed to follow a set of standards. First, the code needed to follow ***perlstyle*** as described in the Perl Programming documentation (Perldoc 2018). Programs needed to contain the program's name, the author or authors' names, and a short description, each as comments at the top. Each section of code required descriptive comments. Pragmata were used to control runtime behavior of Perl. The students were required to include two pragmata. The ***strict*** pragma disabled certain Perl constructs that could behave unexpectedly. The ***warnings*** pragma enabled Perl's optional warnings, which would help debugging programs. When writing backend web programs, Perl programs needed to use the CGI core module.

3. ENVIRONMENT AND SETUP

For each offering, we used the most recently released version of the Raspberry Pi model B. Initially, we used the Raspberry Pi 1 B+ that had a single core ARM 32-bit processor running at 700MHz, 512MB memory, 4 USB ports, and 10/100 Ethernet. The Raspberry Pis ran the Raspbian OS, based upon the 3.12 Wheezy release of Debian. In addition to the Raspberry Pi, the students needed to purchase a power supply, keyboard, micro-SD card, case, and a USB wireless Ethernet (Wi-Fi) adapter. More recent offerings have used the Raspberry Pi 3B which has a quad core 1.2GHz processor, 1GB memory, and built-in Wi-Fi (eliminating the need for the students to purchase a USB Wi-Fi adapter). Unfortunately, the campus bookstore was not, and is still not, able to order Raspberry Pis. Therefore, the students were given links to multiple on-line vendors from whom they could purchase either the individual components or kits. The cost for a fully configured Raspberry Pi was less than a typical textbook.

Since each student would have their own Raspberry Pi that they would use in and out of class, they would need to be able to access it not only in lab, but also at other locations. The Information Technology Services (ITS) group is very focused on ensuring that faculty has access to all necessary resources. Working together, we determined that the best way to connect the Raspberry Pis in lab would be via Wi-Fi, and added an HDMI cable to the secondary monitor on each of the lab's Windows PCs. While a bit cramped at a given workstation, this allowed the students to get to their e-mail and other resources while also directly connecting to their Raspberry Pi's console.

By using the college's Wi-Fi, the Raspberry Pis could connect to the network from any location on campus (Figure 3). As students became more comfortable with using their Raspberry Pi via the network, many students opted to leave their Raspberry Pi in their dorm room and connect from the lab using ***PuTTY***[i]. Instructions were also provided on how to configure the Raspberry Pi to work on other Wi-Fi networks for those students who lived off-campus.

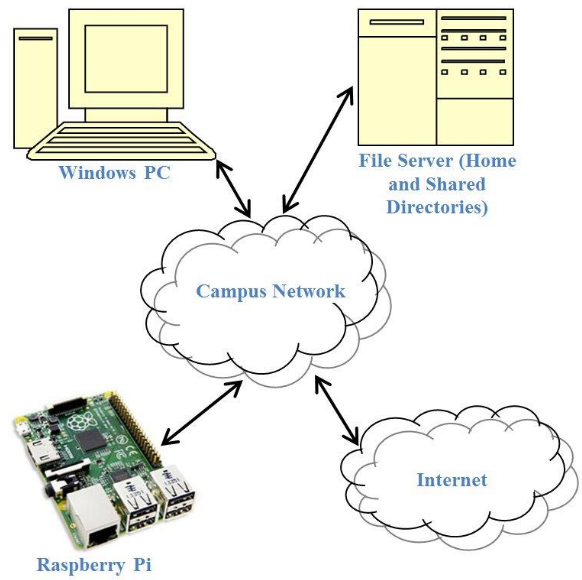

Figure 3 – Campus network environment

In order to get the students up and running as quickly as possible several customizations were made to the base Raspbian operating system, using the then most recent release of Raspbian. The first several customization items related to the wireless network. The college Wi-Fi network was added to the WPA supplicant configuration file. In addition, a shell script was added as part of the boot sequence that automatically sent out an e-mail with the system's network information (***ifconfig***), which included the current IP address. This enabled the student to remotely access their Raspberry Pi even if their IP address changed. In order to enable e-mail, an SMTP relay was configured to use a common Gmail account that was created for the course. Email utilities (***ssmtp***, ***mailutils***, and ***mpack***) and ***Lynx*** (a text based web browser) were installed. The system was then configured to boot to the command line interface, and to use US English. Finally, since there was no way to recover a lost password, a "csprof" account with full root access was added. This account would allow me to log in and perform any administrative tasks, including resetting the student's password. The students were informed of the existence of this account, and they were reassured that the account would not be used to access their system without their explicit consent. The students were then given until the beginning of the second lab to copy the customized version of Raspbian to their micro-SD card.

Students were given read-only access to the materials for each lab via a shared Windows drive. The materials included instructions, sample code, and support files. Students would copy the material to a lab folder on their own Windows home directory. ITS has a secure Linux server that automatically maps a user's home directory upon login. Using ***SFTP***, students would then copy any necessary files from their lab folder under their home directory to their Raspberry Pi. At the end of the lab, the students would use SFTP to copy their work back to their lab folder. This provided two benefits. The first benefit relates to disaster recovery. Since all files that the student modified on the Raspberry Pi were copied to their lab folder, if there was a catastrophic failure of their Raspberry Pi, recovery simply consisted of imaging a new micro-SD card, resetting the system password and name, and copying all of their files back to the Raspberry Pi. The second benefit relates to printing. Rather than having to configure the Raspberry Pis to work with the network printers, students were able to print off their work from the Windows PCs using ***Notepad++***[ii].

4. LABS

The students needed to complete eleven labs over the course of the semester (Table 4). Labs were run with students working in pairs. The lecture prior to each lab provided the students with scaffolding for each of the lab topics. In addition, the students needed to complete a pre-lab for all but the final lab.

Pre-labs (Appendix A) typically consisted of several readings followed by a short on-line multiple choice quiz on the reading material. In preparation for later labs, the pre-lab had the students install software packages, such as the Apache web server. A number of the labs (Appendix B) ended with reflection questions that were meant to make the students think critically and creatively about some aspect of the lab. Three of the labs, von Neumann (lab 7), Python (lab 10), and Artificial Intelligence (lab 11), were common to all flavors of Introduction to CS and were not modified. The discussion that follows and the appendices are limited to the labs, or portions of the labs, where the students used their Raspberry Pis.

Lab Number	Description
1	Linux command line
2	Configure individual Raspberry Pi
3*	Gates and Circuits – Standard input via Perl
4	Loops and conditional logic
5	Arrays and subroutines
6	Apache and dynamic HTML
7**	von Neumann architecture
8*	Alice - ping/traceroute - CGI
9*	Operating Systems - Processes
10**	Python
11**	Artificial Intelligence

Table 4 – Lab Descriptions

* Modified common lab
**Common lab across all sections.

The first lab was run with the students connecting to one of several Raspberry Pis that I had placed on the network. This ensured sufficient time for the students to procure their own Raspberry Pi and to copy the course's version of Raspbian OS to their micro-SD card before they needed to use them in lab. In this lab, the students learned basic Linux commands and about the network environment that they were using. The flow of Lab one is summarized in Table 5. Objectives for this lab included the ability to identify the components of the networking environment, and to demonstrate how shell scripts can be customized to perform specific tasks.

1. Connect to a remote Raspberry Pi via ***PuTTY***
2. Interact with the Linux BASH command line
   a. List the contents of a directory
   b. Display files
   c. Change file permissions
   d. Run shell scripts
3. Use GNU ***Nano***[iii] text editor to modify an existing shell script (Figure 4)
4. Use ***sftp*** to transfer files
5. Use ***man*** to access the Linux on-line reference manuals to discover various options for system commands

Table 5 – Lab 1 Flow

Figure 4 – Nano editor

The second lab began by having the students set up their own Raspberry Pis. Depending upon the number of upgrades issued since I created that semester's course's version of Raspbian, the students then patched their systems with the most recent update using the Advanced Packaging Tool ***apt-get***. If the upgrade would take a significant amount of time, the students were instructed to perform the upgrade before the next lab. The flow of Lab two is summarized in Table 6. Objectives for this lab included having to describe the steps necessary to set up a Raspberry Pi, and to explain how arguments are passed to a shell script.

1. Use the ***raspi-config*** utility to
   a. Change the default password
   b. Set the host name
   c. Expand the filesystem to use all of the space on their micro-SD card
2. Customize a provided shell script to send the system's network information to their e-mail account
3. Register the system on the campus Wi-Fi
4. Use the Lynx text based web browser to perform a Google Search (Figure 5)
5. Patch the system
6. Use BASH pipes and redirection

Table 6 – Lab 2 Flow

During lecture, programming examples were provided in Perl. Starting with the third lab, the students began modifying and writing simple Perl programs on their Raspberry Pis. The fourth lab built on this and introduced loops and conditional expressions. The fifth lab introduced one dimensional arrays and subroutines. Some Perl programming topics, such as string manipulation, were covered in lecture and homework, and were not standalone lab topics.

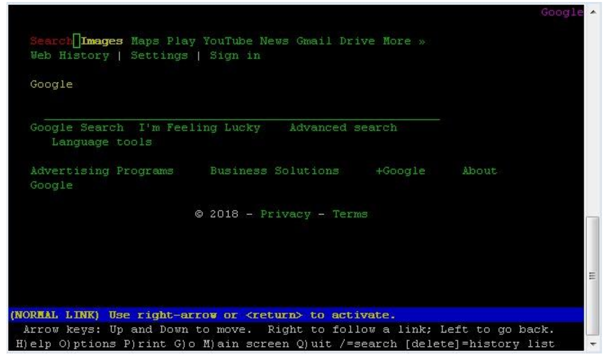

Figure 5 – Text based view of Google

Lab six had the students set their Raspberry Pi up as a web server. So as not to take up excessive lab time, the students installed Apache2 as part of the pre-lab. By the end of the lab they had created their own CGI program that displayed the current date and time as a dynamic web page. The flow of Lab six is summarized in Table 7. Objectives for this lab included the ability to identify the directories used by Apache, and to demonstrate how to manage Apache.

1. Configure Apache
2. Setup directories for
   a. HTML files
   b. Images
   c. CGI programs
3. Edit HTML using nano
4. Create CGI program
5. Monitor Apache's processes

Table 7 – Lab 6 Flow

Lab eight found the students building upon Lab six. The lab had the students look at how packets transverse the network using the ***ping*** and ***traceroute*** commands. They then explored how HTML forms pass data to backend programs.

Building upon Java applet simulations for process management which was common to all flavors of Introduction to CS, Lab nine allowed the students to interactively explore how CPU prioritization of a given process impacts other processes running on a system. Table 8 summarizes the flow of Lab nine.

1. Manage concurrently running jobs with
   a. ***kill***
   b. ***fg***
   c. ***bg***
2. Monitor running processes with
   a. ***ps***
   b. ***top***
3. Adjust process priority with ***nice***

Table 8 – Lab 9 Flow

The primary objective of this lab was for the students to compare and contrast how processes ran under contention and when set with varying priorities. The students were provided with two shell scripts: timehog.sh and longloop.sh. The timehog.sh script repeatedly copied blocks of 1024k zeros to the null device. Left unchecked, this script could utilize all available CPU cycles. The longloop.sh script repeatedly calculated 1000 MD5 checksums. The students noted how long it took longloop.sh to run with and without timehog.sh running in the background, and by changing the priority of the two scripts with the ***nice*** command.

5. HOMEWORK ASSIGNMENTS

While lab assignments were team efforts, all of the homework assignments were individual efforts. There were a total of five homework assignments. In order to emphasize that CS is not just coding, the "programming" portion of the first homework provided the students with specifications for several projects, and they were tasked with developing algorithms for each one. Several of the projects appeared as coding tasks in subsequent homework assignments. Rather than the typical situation where students struggle as they attempt to write code from their heads, the students were able to code from the graded/corrected copy of their algorithms.

The homework assignments reinforced the students' lab work. The second homework assignment had the students write a program to print out a multiplication table using nested loops. The third homework assignment required the students to use a one dimensional array to compare two compound interest scenarios. In the fourth homework assignment students created their own subroutines to manipulate strings.

Their final programming homework assignment was to develop an application that used a simple HTML frontend to pass data to their Perl CGI backend for manipulation, and then displayed the results as an HTML document. The students were given the choice of several scenarios to choose from. These choices included taking a name and producing output based on the lyrics of Shirley Ellis' Name Game song, taking an order for a cookie shop, or translating text into Pig Latin.

6. STUDENT REACTION

Given that the text based environment used in this flavor of the course was drastically different than the GUI environment used by any of the other flavors, I was interested in determining how well the course prepared them for subsequent CS classes. An on-line survey was sent to the 128 students who had taken this flavor of the course more than a year previously in order to find out if they would be interested in participating in a focus group discussion about their experience. Six students participated, all of whom had also taken at least one other CS course. Two of the six were Accounting majors, and the other four were CS majors. Three were male and three were female.

The general consensus was that initially the course was intimidating. For most of the students this was their first formal computer science course. However, they all agreed that it was a worthwhile experience, and its benefits extended beyond the classroom. The following are excerpts of the discussions.

"The Linux portion of it was such a foreign concept to me. It ended up being the most rewarding part because my internship; and every other interview that I've been in on they've asked me if I am comfortable on a Linux terminal and things like that and I've used it a lot. So, although it was the most, you know, it was the most anxious part for me for the course, it pays dividends."

"I actually know and kind of use it (the Raspberry Pi) now. Yeah, I use it for some like home automation stuff, making a home homebridge like certain products that didn't talk to each other."

"I came in with no knowledge and I was a nervous wreck the whole time. But I made it through and it was probably the course that made me decide on what major I wanted to choose which ended up being computer science."

"You know, I've even used the Nano editor again because, you know, working in a terminal you have the VIM or the Nano one, so it's like that part was very helpful."

"I thought it was a good basis because even before going in I heard that it was the hardest 110 actually, just concept wise. So I think going in with that kind of structure of like a harder 110 it ended up helping me with my further courses."

7. REFLECTIONS AND NEXT STEPS

By and large, the Linux flavor of Introduction to CS was well received. As with any journey, there were some bumps in the road. Thankfully they were all navigable.

One of the first bumps relates to the use of Wi-Fi. By its nature, Wi-Fi is a shared medium. This makes it very difficult to guarantee bandwidth. ITS does an admirable job maintaining the network. However, periodically situations, such as an iOS update or the World Cup, would spike demand and slow down access to the Raspberry Pis. Given that rewiring the lab to double the number of Ethernet drops for this one course is not a practical solution, we have continued to use Wi-Fi. On the rare occasion when the networks slowed down, it provided an opportunity to discuss networking with the class, and the pros and cons of wired and wireless environments.

The students used SFTP to transfer sample code and finished programs between their lab folder on their own Windows home directory and their Raspberry Pi. This worked well once the students understood the difference between the bash shell prompt and SFTP prompt. However, several students in the focus groups mentioned that during job interviews they were asked about their experience with version control. Therefore, while I would still introduce SFTP at some point in the course, it may be beneficial for the students to use GitHub instead of SFTP. I could then treat each lab and homework assignment as its own project.

After the first offering, I was fortunate to be able to have lab assistants who had previously taken the course and were able to assist the current students. These positions were offered to students who had excelled in the class, and had been the “go to” for other students. I used them to run through the labs ahead of time to look for bugs, typos, and for any items that were not clearly explained. While they assisted in answering questions during the lab, they neither gave formal instruction nor graded any of the material.

Several of the other flavors of the course use Finch robots[iv] to teach programming concepts. In these, the students manipulate the color of the Finch’s beak and write a program that uses the Finch’s sensors to avoid obstacles. Giving students the ability to control real world objects with their programs can be a very powerful learning experience. I am planning to integrate the Finch into several of the existing labs.

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Appendix

Appendices can be found on-line:

Appendix A – Pre-Lab
https://drive.google.com/open?id=1UjCdDDX82QLUCmKeetHMkvInjzy3liEv

Appendix B - Lab
https://drive.google.com/open?id=1EcrKZo9yLYY5-iVuWAH-ZGNS50XDk97T

Interim Awardee Outcomes after Four Years of a STEM Scholarship Program

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Abstract

This paper describes the results of a four-year follow-up of need-based scholarship awardees at a community college as they made progress toward their goal of associate's degrees and/or bachelor's degrees in Science, Technology, Engineering, and Mathematics (STEM) fields. From 2014 through 2018, through National Science Foundation funding, need-based scholarships were offered for full-time STEM students with a minimum grade point average, and U.S. citizenship, or status as permanent resident alien or refugee alien. Spatial skills testing and practice, faculty mentoring, and a monthly luncheon workshop series with information on career and transfer were used to increase associate's and bachelor's degree attainment or transfer in STEM fields. Outcomes of these efforts are described, including spatial skills attainment and practice, and time elapsed from initial enrollment in the community college to subsequent bachelor's degree attainment. Outcomes by gender, race/ethnicity, and initial mathematics placement of awardees are also provided.

Keywords: spatial skills, mentoring, scholarships, transfer rate, underrepresented, STEM, time to degree

1. INTRODUCTION

Regarding undergraduate enrollment, in 2014 Blacks, Hispanics, and other racial/ethnic groups underrepresented in STEM fields were more likely to be enrolled in public 2-year institutions; whereas Whites and Asians were more likely to be enrolled in public 4-year institutions (NSF NCSES, 2017). Blacks make up 13.2% of the U.S. population, and Hispanics comprise 17.5% of the U.S. population (Chang, 2015).

Women's bachelor's degree attainment in science and engineering declined in every field from 2004 to 2014 (Espinosa, 2015). In 2014, women earned 18.1% of computer science bachelor's degrees and 19.8% of engineering bachelor's degrees (down from 25.1% and 20.5% in 2004). The proportions of bachelor's degrees earned by Blacks in computer science and engineering in 2014 fell to 9.75% and 3.83% (down from 10.44% and 4.99% in 2004). In 2014, Black women earned 2.61% of computer science bachelor's degrees and 0.99% of engineering bachelor's degrees (down from 4.63% and 1.70% in 2004). The proportions of bachelor's degrees earned by Hispanics in computer science and engineering in 2014 rose to 9.74% and 9.56% (up from 6.27% and 6.93% in 2004). Hispanic women earned 1.79% of computer science bachelor's degrees in 2014 (nearly flat from 1.77% in 2004), and earned 2.08% of engineering bachelor's degrees (up from 1.72% in 2004) (NSF NCSES, 2017).

The National Science Foundation's Division of Undergraduate Education provides a program known as Scholarships for Science, Technology, Engineering, and Mathematics (S-STEM) that can address the underrepresentation described above (NSF, 2017). This program makes grants to institutions of higher education, which in turn are responsible for selecting scholarship recipients and reporting demographic information about student scholars. Scholarship recipients must be academically talented but financially needy and enrolled full-time in one of these major programs: computer and information sciences, engineering, mathematical sciences, biological sciences, physical sciences, geosciences, or technology areas associated with those fields. Individual scholarships cannot exceed $10,000 per year.

The individual college/university determines award criteria, including minimum GPA and eligible major programs for the S-STEM program. However, NSF guidelines specify that students who are awarded these scholarships must be U.S. citizens, permanent residents, nationals, or refugees.

This paper describes degree and other outcomes after four years for a specific S-STEM scholarship program at the Community College of Baltimore County. The scope of the paper includes demographics of the combined CCBC awardees, and transfer and graduation rates, for all awardees and certain subgroups of awardees, including by gender, race and ethnicity. Results of spatial skills testing and practice are provided. Awardees' time elapsed from initial enrollment at this community college to bachelor's degree attainment is also presented.

2. INSTITUTIONAL INFORMATION

The Community College of Baltimore County (CCBC) is a public two-year college system with three campuses serving the greater Baltimore metropolitan area. The Fall 2015 combined credit enrollment was 22,179 students of which 29% were full-time students. Thirty-nine percent (39%) of the credit students were African American, and 60% of credit students were female. In FY 2016, CCBC awarded 2,194 associate's degrees.

From 2012 to 2017, although CCBC's total fall enrollment steadily declined (falling 23% over that period), enrollment in STEM associate's degree programs increased 10%. Within STEM associate's degree programs at CCBC, the largest enrollment increase occurred in the new Information Systems Security (also called Cybersecurity) program which grew 277%. Although the total number of associate's degrees awarded at CCBC was unchanged from 2012 to 2017, there was a 69% increase in the number of STEM associate's degrees awarded at CCBC (MHEC, April 2018, May 2017, March 2018). In 2017, 13% of CCBC's enrollment was in STEM programs. These increases are shown in **Figure 1** (see Appendix).

3. MCIS SCHOLARSHIP PROGRAM AT CCBC

MCIS Scholarship Program

From Fall 2014 through Spring 2018, 101 full-time CCBC students (34 female and 67 male) majoring in certain STEM fields were awarded renewable MCIS semester scholarships through NSF funding. Awardees retained their scholarships for one or more semesters with the average length being 2.6 semesters. Eligible major programs for MCIS included the following transfer and career programs: Computer Science (COSC), Engineering (ENGR), Mathematics (MATH), Physics (PHYS), Information Systems Security (ISS), Engineering Technology (ET), Information Technology (IT), and Network Technology (NT). **Figure 2** shows the distribution of awardees among these major programs. Engineering (31/101) and Computer Science (23/101) are the CCBC major programs with the highest numbers of MCIS awardees. Over half of the 101 awardees were in COSC or ENGR programs. Thirty-four percent (34/101 = 34%) of the 101 awardees were female.

These awardees have been highly successful in graduating with associate's degrees and/or transferring to 4-year institutions where 19 have already earned bachelor's degrees.

Selection Process and Demographics of MCIS Awardees

Each semester new, renewal, and transfer MCIS scholarship applications were received. They were due by June 1 for Fall awards, and by December 1 for Spring awards. Members of the Steering Committee, comprised of representatives from the targeted MCIS programs met early in July and

January to review applications and transcripts, select scholarship awardees, and determine whether any of the renewal or transfer awards for the upcoming semester should be probational. Probational awards were made to awardees who fell just short of meeting the renewal criteria of completing 12 or more credits with 2.8 GPA or higher.

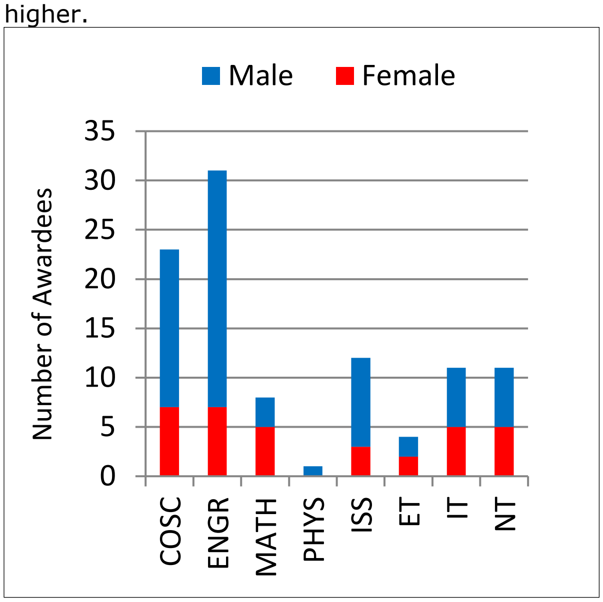

Figure 2. All 101 MCIS STEM Awardees from Fall 2014 through Spring 2018 by Major Program and Gender.

Probational awards were made to awardees who fell just short of meeting the renewal criteria of completing 12 or more credits with 2.8 GPA or higher. Probational awards provided lower financial support (generally 25% lower) along with the incentive to improve grades. Students whose academic performance was significantly lower than required were not awarded renewal scholarships.

The distribution of all credit students at CCBC in Fall 2014 by racial/ethnic group as self-described at course registration was as follows: White 45%, Black 39%, Asian 7%, Hispanic/Latino 5%, and Other/Unknown 4% (MHEC, May 2017). The institutional rate of Pell awards provides one indication of the level of unmet financial need. In Fall 2015, CCBC had 42.3% Pell enrollment compared to 34.8% Pell enrollment at all Maryland community colleges.

Minority groups that have been under-represented in STEM fields nationally are represented among the 101 MCIS awardees from Fall 2014 through Spring 2018 in proportions close to their population percentage at CCBC. In particular, 38% of the 101 awardees self-identified as White, 37% as Black, 20% as Asian, 5% as Multiple Races, and 1% as Hawaiian/Pacific Islander. Among all these, 5% were Hispanic/Latino, as shown in **Figure 3**.

A total of 259 (81F/178M) semester scholarship awards were made over 4 years, for the $540,000

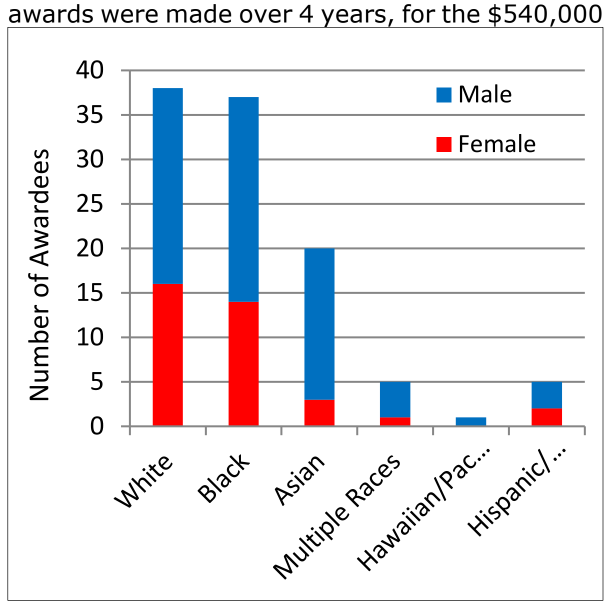

Figure 3. All 101 MCIS Awardees from Fall 2014 through Spring 2018 by Race/Ethnicity and Gender.

of scholarship funds. The average semester award was $2,124, but each semester the individual awards were fixed percentages of each awardee's remaining unmet financial need after his/her other awards and subsidized loans were taken into consideration. As a result, actual award amounts ranged from $80 to $5140 per semester.

Faculty Mentoring

Each MCIS awardee was paired with a faculty mentor from his/her major field and met at least every other week for the first six weeks of the semester and monthly thereafter, either in person, via email and/or by phone. Awardees completed a Mentoring Agreement that they reviewed with their mentor. Mentors maintained a mentor log documenting the meetings and detailing what actions the scholar needed to take before the next meeting.

With high numbers of engineering and computer science awardees, several additional faculty members became mentors for the MCIS scholars, joining returning mentors for an eventual total of 22 faculty mentors. Mentors provided advice and guidance when issues arose, and developed and managed an Individual Academic Learning Plan to ensure that awardees were on track for academic success. Some mentors also assisted students with obtaining employment. Since traditional CCBC students are not assigned an academic advisor to guide them, the MCIS mentorship program was a major benefit for awardees. Students found that through their participation in the program, they also got to know other STEM faculty who were happy to provide assistance in addition to their own mentors.

Incorporating Spatial Skills Training

The ability to think in terms of spatial relations is an important skill for STEM students as they take courses toward their career goals. "Spatial thinking refers to a set of mental skills that enable us to reason about space and the relationships between objects," (Gagnier & Fisher, 2016). Research suggests that spatial visualization abilities are important for success in STEM fields such as engineering, chemistry, computing and mathematics (Sorby, 2009; Metz, Jarosewich & Sorby, 2016; Gagnier, & Fisher, 2016). MCIS scholarship students were required to participate in completing the Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R). The test consisted of thirty multiple choice questions taken over a twenty-minute time limit, aimed at assessing the spatial ability of students. The goal of participating in the test was to improve student spatial thinking skills for those with a low score. Students that scored less than 70% on the test were asked to participate in one hour weekly to bi-weekly workshops to practice their visualization skills for the duration of the semester. Workshops consisted of practice sketching sessions of visualization skills and examining 3D rotations. At the end of the semester, students were requested to take the PSVT:R again. These workshops were conducted on two of CCBC's three main campuses on a rotating basis.

Originally, students would take the test using a traditional paper version, which was graded manually or by Scantron. However, during the Spring 2016 semester, as CCBC was one of the community college partners to the Spatial Skills Instruction Impacts Technology Students (SKITTS) project an online version of the test and workshops was used (Metz, Jarosewich & Sorby, 2016), and (Sorby, Metz & Jarosewich, 2016). This model allowed students to make the choice to attend all of the workshops online, face-to-face or a combination of the two as a blended format. The online content was administered through Blackboard and was expanded so that students in other courses outside of the MCIS program could practice with the material. The online course included ten modules composed of video lectures, video examples, PowerPoint notes, practice and additional sketching exercises that were assigned. Materials were based on the Spatial Course Learning Resources (Sorby, 2009). The Blackboard course was created as a self-enrolling organization that was open to students throughout the campus.

Students could submit practice sketches as scanned documents through email or through the Blackboard site. Some students submitted paper versions of their sketches in-person at one of the campus locations. Feedback was provided to students in all formats. A substantial additional benefit of the spatial skills workshop was additional support provided to students. Workshops allowed additional interaction with faculty in an informal learning environment that allowed for spontaneous discussions about courses, majors, and career information. Feedback from students indicated that this additional time with faculty outside of the classroom was beneficial.

Spatial Skills Testing of Awardees

At the first MCIS workshop of each semester in August and January, new MCIS awardees were given the PSVT:R spatial skills test. Also at the first workshop of the semester these requirements of being in the program were addressed to make sure new awardees understood them: attending monthly workshops, regularly meeting with a faculty mentor, and practicing spatial skills if they scored less than 70 on the PSVT:R. During the first two years, spatial skills practice was provided through spatial skills workshops (bi-weekly to monthly). In the last two years, practice was provided through various format options, such as face to face, hybrid, and online modules using Blackboard. Students were asked to confirm that they were willing and able to make the commitment. However, earning a "passing" score of 70% or higher on the PSVT:R was not an MCIS scholarship eligibility criterion.

Examining all 101 MCIS scholarship students, 47 scored at or above the 70% threshold (47/101) yielding a 46.5% pass rate on first attempt. Thus 54 students were strongly encouraged to participate in the spatial skills workshops. To be considered as completing the workshops, students had to participate in at least 80% of workshop sessions. This was also true for online students, where they were required to submit at least 80% of all practice materials and additional tasks.

After completing the workshops, there was an average positive change of 16 points, for students retaking the PSVT:R. The average of the highest scores obtained for the PSVT:R from all students was 67.6%. This score includes scores for students who completed the workshops (and re-took the exam for a potentially higher score), and those who passed on the first attempt. From this group the average highest score for females was 62.3% and 70.3% for males. Examining all post PSVT:R scores, 63 students or 62.4%, were now at or above the 70% threshold. This included 18 females (18/34 = 53% of females) and 45 males (45/67 = 67% of males) that were now in the passing range. Additionally, the average high score for Black students was 56.4%, Asian students 62.1%, and 79.3% for White students. Four students did not self-identify with one of these racial/ethnic groups.

Awardee Leadership and Volunteer Roles
MCIS scholarship awardees were encouraged to participate in the service component of the MCIS scholars program. The service component of the program gives students the opportunity to gain valuable leadership skills, become more involved with CCBC, build their resume, and expand their network. The Student Ambassador Program is a leadership opportunity for MCIS scholars who are dedicated to serving and representing the college. Student Ambassadors provide campus tours, serve as CCBC representatives and perform duties at various CCBC campus and community events. Some Computer Science/Information Technology, Information Systems Security, and Network Technology students volunteered their services by working in the Homework Lab as tutors. Students select two hours per week that they sit in the Homework Lab to assist students on academic subjects by furnishing information, helping solve problems, offering support, and suggesting study tips and strategies. The Lab presents a good option not only for tutoring but also for building peer-mentoring relationships. Each semester there were 4 to 8 MCIS student computer lab volunteers. Several awardees volunteered as tutors for self-paced developmental mathematics classes. Working as a tutor provided some of the best workplace training possible; MCIS tutors were dependable motivated, caring and responsible, all of which are valuable qualities to prospective employers and other key stakeholders.

Interventions Used
During the four year grant period, there were no MCIS dropouts from the program. Several interventions incorporated in the program contributed to increased retention and completion with a specific focus on minority students and females. Some of the interventions used were one-day workshop in August focusing on STEM programs, guest speakers from STEM fields, optional internships for awardees, CCBC Technology, Engineering and Mathematics (TEM) Pathway workshops on resume writing, monthly mentoring of all awardees by STEM faculty, and monthly luncheon workshops for awardees and faculty mentors.

STEM faculty mentoring played a pivotal role in MCIS student success and retention. Faculty focused on academic adjustment, retention, and overall educational success. Mentors were proactive in maintaining consistent and high retention rates by advising on course selection and schedules prior to each semester, checking periodically during the semester with mentees on their academic standing, building relationships, offering tutoring sessions for programming courses facilitated by computer programming faculty, and more.

Efforts to Increase the Transfer Rate
The MCIS scholarship program encouraged awardees to continue their STEM studies at four-year institutions. To assist awardees to complete bachelor’s degrees in these fields, the MCIS project proposal stated that 20% of scholarship funds would "follow" awardees who had transferred. MCIS scholarship funding was awarded to former awardees who had earned an associate’s degree, or at least 45 credits, in an MCIS-eligible program at CCBC before transferring to a four-year institution. In addition, students kept their STEM faculty mentor while transitioning to the four-year college.

Awardee Transfers
MCIS awardees who transferred to a four-year institution from CCBC with an associate’s degree, or at least 45 credits in an eligible STEM program, were given the option of retaining their MCIS scholarship for up to 2 semesters upon transferring. This enabled students to reach greater success in a STEM field by drawing attention to the possibility of transfer to a four-year school for students who otherwise might not have considered transfer. Transferring awardees had to provide documentation of their: admission and full-time status at the four-year institution in an MCIS-eligible STEM major, unmet financial need, and successful completion of prior coursework in an MCIS-eligible STEM degree program at CCBC.

Because of the large number of MCIS awardees who transferred, in some semesters the percent of available funding allocated for transfer awards was as high as 32%. However, due to the higher costs of attendance at a four-year institution (compared to attendance at CCBC), the percentage of their unmet financial need that was awarded to transfer awardees was never as high as the percentage for awardees still at CCBC. Of the 259 (81F/178M) semester scholarship awards that were made over 4 years, 85 (24F/61M) were transfer awards made to former CCBC MCIS awardees who had transferred to a four-year institution to pursue a bachelor's degree in an MCIS-eligible STEM program.

Awardee Internships

Awardees were encouraged to apply for internships, and scholars were provided assistance and information about various internship opportunities. Two MCIS awardees received internships from Constellation, a local Exelon energy company. Another awardee, a computer science major, participated in the REU Site: *Interdisciplinary Program in High Performance Computing* in the Department of Mathematics and Statistics at the University of Maryland, Baltimore County (UMBC) in Summer 2017 (Della-Giustina et al, 2018).

Two MCIS awardees (both engineering majors) were selected for a 6-week paid summer internship program funded by NIH called *BUILD a Bridge to STEM* at UMBC. This program focuses on biomedical and behavioral sciences and is open to students from area community colleges.

In addition, MCIS scholars were encouraged to attend the TEM Pathways workshops with initiatives that invite community organizations to speak on internships. Some of the firms that are providing Cybersecurity internships for CCBC students are: First Financial Federal Credit Union (second consecutive year), MECU of Baltimore (second consecutive year), CCBC IT Services (first year), Exelon Corporation (first year), and Whiting-Turner Contracting Company (first year).

4. AWARDEE OUTCOMES

Sixty-four percent (65/101 = 64%) of the 101 total MCIS awardees have transferred to a 4-year institution, and an additional 19% have earned associate's degrees but did not transfer to a 4-year institution. As shown in **Figure 4**, 64% of the 101 MCIS awardees have earned associate's degrees, and 19% have earned bachelor's degrees (as of July 2018). And 69% have earned at least one of these degrees.

MCIS Awardee Outcomes by Initial Mathematics Placement Level at CCBC

Students entering CCBC take an *Accuplacer* mathematics placement test which determines their initial mathematics placement. Over half of entering students have an initial mathematics placement that is developmental. That is, the student places into one of the 3 non-credit developmental mathematics courses: MATH 081 Pre-Algebra, MATH 082 Introductory Algebra, or MATH 083 Intermediate Algebra.

MCIS awardees at CCBC were required to have eligibility for MATH 083 Intermediate Algebra, or higher, at the time of their award. They could obtain this eligibility through their initial mathematics placement, or by first completing any needed developmental mathematics courses. Among the total 101 (34F/67M) CCBC MCIS awardees from Fall 2014 through Spring 2018 were 34 (17F/17M) whose initial mathematics placement level at CCBC was developmental. Although most (25) of these 34 awardees initially placed into MATH 083, there were 7 who initially placed into MATH 082, and 2 who initially placed into MATH 081. The outcomes and success rates for the 34 awardees with initial placement into developmental mathematics, and for the other 67 awardees with initial placement into non-developmental mathematics are shown in **Figure 5**. Among those who initially placed into developmental mathematics, 79% (27/34) transferred to a 4-year institution or graduated with an associate's degree (but did not transfer) and the other 7 were still enrolled at CCBC in Spring 2018. Among those whose initial placement was into non-developmental mathematics, 85% (56/67) transferred to a 4-year institution or graduated with an associate's degree. Eight (8) of the other 11 in this group were enrolled at CCBC in Spring 2018. The remaining 3 were enrolled at CCBC in 2017 and successfully completed through Calculus II or higher. Among the 101 total MCIS awardees, females formed 50% (17/34) of the developmental initial placement group, and 25% (17/67) of the non-developmental initial mathematics placement group of awardees.

Sixty-eight percent (68%) of awardees with initial developmental math placement have earned associate's degrees compared to 63% of awardees with initial non-developmental mathematics placement. Fifty-six percent (56%) of awardees with initial developmental math placement have transferred to 4-year institutions compared to 67% of awardees with initial non-developmental mathematics placement.

Awardee Outcomes by Gender
Considering all 101 awardees to date from Fall 2014 through Spring 2018, as of July 2018, a total of 64 (21F/43M) awardees (63%) have transferred to 4-year colleges/universities. Overall, 62% (21/34) of the female awardees, and 64% (43/67) of the male awardees have transferred, as shown in **Figure 6**.

Considering all 101 MCIS awardees, as shown in **Figure 7**, at the end of Year Four, 44% of female awardees were in either COSC or ENGR major programs, and 63% of male awardees were in those 2 programs. The ISS program (now called Cybersecurity) also had a higher percentage of male awardees (12%) than female awardees (9%). On the other hand, females had higher percentages of awardees in MATH, IT and NT (45% combined) compared to 20% of male awardees in those 3 programs combined.

Awardee Bachelor's Degrees
Bachelor's degrees have been earned by 19 awardees (19/101 = 19%) to date, including 21% (7/34) of female awardees and 18% (12/67) of male awardees. This is shown in **Figure 6.** Additionally, another 43 (14F/30M) MCIS awardees were enrolled at transfer institutions in 2018. The institutions from which awardees earned their bachelor's degrees were: 11 from University of Maryland Baltimore County (UMBC), 3 from University of Maryland University College (UMUC), 1 from Capitol Technology University, 2 from Towson University (TU), 1 from University of Baltimore (UB), and 1 from University of Maryland College Park. Major programs for those 19 who have earned bachelor's degrees are: IS/IT (5), Cybersecurity (4), Computer Science (2), Mathematics (2), Chemical Engineering (1), Computer Engineering (1), Electrical Engineering (1), Mechanical Engineering (1), Simulation and Game Design (1), and Management of Aging Services (1). This is shown in **Figure 8**. For the 19 MCIS awardees who have earned bachelor's degrees, the elapsed time from initial CCBC entry to bachelor's degree attainment has ranged from 44 months to 119 months, with median time of 60 months (5.0 years), and average time of 65 months (5.4 years).

These times are expected to increase as additional MCIS awardees earn bachelor's degrees. Research funded by Lumina Foundation found that for students with a prior associate's degree, the average time elapsed from initial postsecondary enrollment to a bachelor's degree was 8.2 years. Among bachelor's degree earners with no associate's degree, but with prior enrollment in 2-year institutions, the average time elapsed to bachelor's degree was 6.0 years (Shapiro, Dundar, Wakhungu, Yuan, Nathan & Hwang, 2016).

Awardee Outcomes by Racial/Ethnic Group
As shown in **Figure 9**, to date, 63% of the 101 MCIS awardees transferred to a 4-year institution.

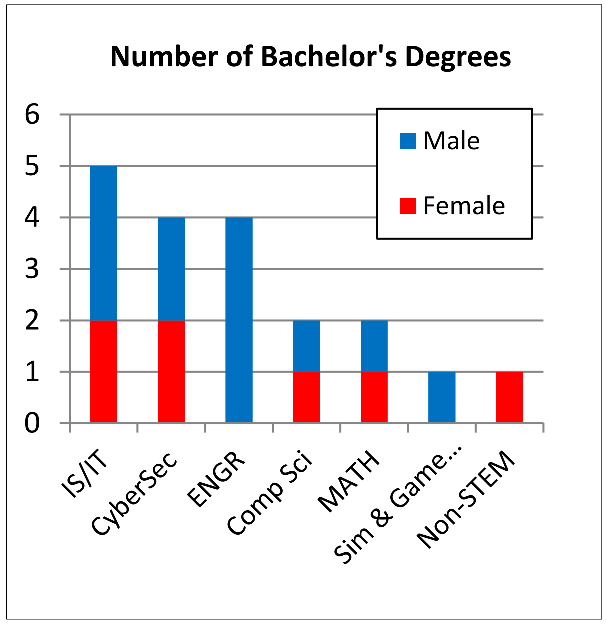

Figure 8. Major Programs for Bachelor's Degrees Earned by 19 CCBC MCIS Awardees from Fall 2014 through Spring 2018 by Gender.

The transfer rate is similar among White and Black awardees (66% and 65%). Although 64% of all awardees have earned associate's degrees, 71% of White awardees, 65% of Black awardees, and 55% of Asian awardees have earned associate's degrees. This is shown in **Figure 10**.

5. CONCLUSIONS

From Fall 2014 through Spring 2018, 101 full-time CCBC students majoring in certain STEM fields received S-STEM scholarships for one or more semesters through NSF funding.

These awardees have been successful in graduating with associate's degrees and/or transferring to 4-year institutions where 19 to date have earned bachelor's degrees.

The transfer rate to 4-year institutions is similar for Black awardees (65% transferred), and White awardees (66% transferred). Black awardees have a higher rate (22%) of earning bachelor's degrees than White awardees (18%). Associate's degree attainment is higher for White awardees (71%) than for Black awardees (65%).

Awardees with initial developmental mathematics placements were less likely (56% vs. 67%) than those with non-developmental math placements to transfer to 4-year institutions and earn bachelor's degrees (12% vs. 22%), but were more likely (68% vs. 63%) to earn associate's degrees.

Female and male awardees were equally likely to earn associate's degrees (65% and 64%), and transfer (62% and 64%) to 4-year institutions.

Sixty-three percent (63%) of bachelor's degrees earned by awardees were in IS/IT, Cybersecurity, Computer Science, and Game Design major programs combined. Twenty-one percent (21%) of earned bachelor's degrees were in Engineering programs, and 5% were in non-STEM major programs.

Initially taking the PSVT:R spatial skills test, only 46.5% of the MCIS students scored above the 70% pass rate. After participating in several spatial skills workshops, students on average improved their spatial skills score by 16 points. MCIS students averaged a 67.6% passing rate overall after re-taking the test. The spatial skills workshops provided students with additional support, faculty interaction and practice with their 3D visualization skills.

Awardees' mean time elapsed from initial CCBC entry to bachelor's degree was 5.4 years, and the median time elapsed to bachelor's degree was 5.0 years, for the 19 MCIS awardees who have already earned bachelor's degrees.

6. ACKNOWLEDGEMENT

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Appendices

CCBC Associate's Degree Program	Enrollment in Program Major						Associate's Degrees Awarded					
	2012	2013	2014	2015	2016	2017	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
* Science	551	624	724	746	749	669	27	33	37	44	42	35
Engineering	494	464	413	406	345	307	13	13	9	20	15	24
Computer Engineering	0	0	9	56	97	99	0	0	0	0	1	4
Electrical Engineering	0	0	7	45	72	69	0	0	0	1	1	3
Computer Science	454	415	442	473	442	470	15	14	28	21	42	27
Secondary Ed - Chemistry	10	9	6	2	2	1	0	0	0	0	0	0
Secondary Ed - Mathematics	26	37	30	26	14	17	2	2	0	1	3	0
Secondary Ed - Physics	4	5	4	4	1	0	0	0	0	0	0	0
Geospatial Applications	31	30	29	42	33	19	1	7	9	1	9	4
Information Technology	257	308	283	304	299	291	26	23	39	33	28	40
Information Systems Security	81	140	139	233	268	305	4	8	32	29	37	45
Network Technology	242	435	438	385	218	172	37	34	47	34	29	30
Engineering Technology	111	140	129	117	89	69	5	8	5	5	10	8
Totals:	2,261	2,607	2,653	2,839	2,629	2,488	130	142	206	189	217	220
CCBC Total Fall Enrollment and Total Associate Degrees	25,188	24,275	22,887	22,179	21,193	19,349	2,132	2,086	2,020	2,200	2,174	2,133
% STEM Enrollment and Degrees	9%	11%	12%	13%	12%	13%	6%	7%	10%	9%	10%	10%

*Biology, Chemistry, Environmental Science, Mathematics, and Physics data are included in the Science program.

Sources: MHEC Trends in Enrollment by Program (April 2018, May 2017, June 2016), MHEC Trends in Degrees and Certificates by Program (March 2018, November 2016, March 2016), MHEC Opening Fall Enrollment (November 2011, December 2012, November 2013, November 2014, November 2015, December 2016, December 2017), and MHEC Data Book 2018, 2017, 2016, 2015, 2014, 2013, 2012, 2011.

Figure 1. CCBC Enrollment and Associate's Degrees Awarded in STEM Programs, 2012 – 2017.

Awardee Outcome	MCIS Fall 2014 – Spring 2018	
	Number of Awardees	% of Awardees
Transferred to 4-yr	64 (21F/43M)	63%
Graduated (Associate's degree but no transfer)	19 (6F/13M)	19%
Still Enrolled (in community college in 2017 or 2018)	18 (7F/11M)	18%
Dropped Out	0	0%
TOTALS:	**101 (34F/67M)**	**100%**
Associate's Degrees:	65 (22F/43M)	64%
Bachelor's Degrees:	19 (7F/12M)	19%
Earned at least one of these degrees (Associate's or Bachelor's):	70 (23F/47M)	69%

Figure 4. Outcomes (as of 7/5/18) for All 101 CCBC MCIS S-STEM Awardees from Fall 2014 through Spring 2018.

	Developmental MATH Level		Non-Developmental MATH Level		Combined	
Awardee Outcome	**Number of Awardees**	**% of Awardees**	**Number of Awardees**	**% of Awardees**	**Number of Awardees**	**% of Awardees**
Transferred to 4-yr	19 (10F/9M)	56%	45 (11F/34M)	67%	64 (21F/43M)	63%
Graduated (Associate's degree but no transfer)	8 (3F/5M)	24%	11 (3F/8M)	16%	19 (6F/13M)	19%
Still Enrolled (in community college in 2017 or 2018)	7 (4F/3M)	21%	11 (3F/8M)	16%	18 (7F/11M)	18%
Dropped Out	0	0%	0	0%	0	0%
TOTALS:	34 (17F/17M)	100%	67 (17F/50M)	100%	101 (34F/67M)	100%
Associate's Degrees:	23 (10F/13M)	68%	42 (12F/30M)	63%	65 (22F/43M)	64%
Bachelor's Degrees:	4 (1F/3M)	12%	15 (6F/9M)	22%	19 (7F/12M)	19%

Figure 5. Outcomes (as of 7/5/18) for All 101 CCBC MCIS S-STEM Awardees from Fall 2014 through Spring 2018 by Initial Mathematics Placement Level upon Entry to CCBC.

	Females		Males		Combined	
Awardee Outcome	**Number of Awardees**	**% of Awardees**	**Number of Awardees**	**% of Awardees**	**Number of Awardees**	**% of Awardees**
Associate's Degrees:	22	65%	43	64%	65	64%
Transferred to 4-yr	21	62%	43	64%	64	63%
Bachelor's Degrees:	7	21%	12	18%	19	19%
TOTAL AWARDEES:	34		67		101	

Figure 6. Outcomes (as of 7/5/18) for All 101 CCBC MCIS S-STEM Awardees from Fall 2014 through Spring 2018 by Gender.

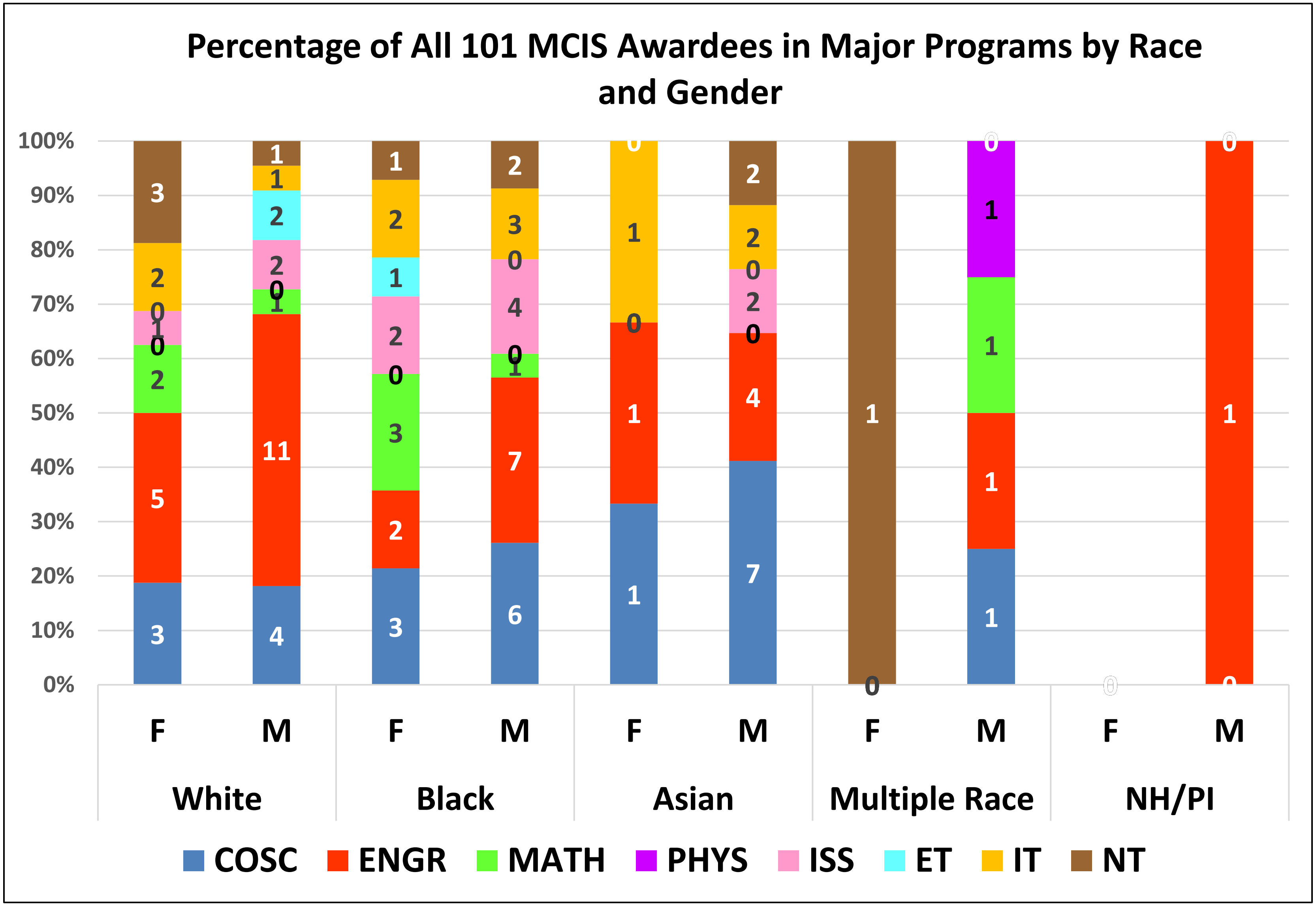

Figure 7. Percentage of All 101 *MCIS* Awardees in Major Programs by Race and Gender through Spring 2018 (showing number of awardees in each group at end of Year 4)

Awardee Outcome	MCIS Awardees Fall 14 – Spring 18		Racial/Ethnic Group									
			White		Black		Asian		Other		Hispanic/Latino	
	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees
Transferred to 4-yr	64 (21F/43M)	63%	25 (11F/14M)	66%	24 (8F/16M)	65%	11 (2F/9M)	55%	4 (0F/4M)	67%	3 (1F/2M)	60%
Graduated (Associate's degree but no transfer)	19 (6F/13M)	19%	8 (3F/5M)	21%	5 (2F/3M)	14%	4 (0F/4M)	20%	2 (1F/1M)	33%	0	0%
Still Enrolled (in community college in 2017 or 2018)	18 (7F/11M)	18%	5 (2F/3M)	13%	8 (4F/4M)	22%	5 (1F/4M)	25%	0	0%	2 (1F/1M)	40%
Dropped Out	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
TOTALS:	**101 (34F/67M)**	**100%**	**38 (16F/22M)**	**100%**	**37 (14F/23M)**	**100%**	**20 (3F/17M)**	**100%**	**6 (1F/5M)**	**100%**	**5 (2F/3M)**	**100%**
% Female in that Racial/Ethnic Group:	**34/101**	**34%**	**16/38**	**42%**	**14/37**	**38%**	**3/20**	**15%**	**1/6**	**17%**	**2/5**	**40%**

Figure 9. Awardee Outcomes for 101 CCBC MCIS S-STEM Scholars by Racial/Ethnic Group.
Note: Hispanic may be any race. Awardees declaring as Hispanic/Latino self-identified as 2 White, 2 Multiple Races, and 1 Black.

Awardee Degree Outcome	MCIS Awardees Fall 14 – Spring 18		Racial/Ethnic Group									
			White		Black		Asian		Other		Hispanic/Latino	
	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees	Number of Awardees	% of Award-ees
Associate's Degrees:	65 (22F/43M)	64%	27 (11F/16M)	71%	24 (9F/15M)	65%	11 (1F/10M)	55%	3 (1F/2M)	50%	1 (0F/1M)	20%
Bachelor's Degrees:	19 (7F/12M)	19%	7 (3F/4M)	18%	8 (4F/4M)	22%	2 (0F/2M)	10%	2 (0F/2M)	33%	1 (0F/1M)	20%
Earned at least one of these degrees (Associate's or Bachelor's):	70 (23F/47M)	69%	28 (12F/16M)	74%	26 (9F/17M)	70%	12 (1F/11M)	60%	4 (1F/3M)	67%	1 (0F/1M)	20%
TOTALS:	101 (34F/67M)	100%	38 (16F/22M)	38%	37 (14F/23M)	37%	20 (3F/17M)	20%	6 (1F/5M)	6%	5 (2F/3M)	5%

Figure 10. Degree Outcomes for 101 CCBC MCIS S-STEM Scholars by Racial/Ethnic Group
Note: Hispanic may be any race. Awardees declaring as Hispanic/Latino self-identified as 2 White, 2 Multiple Races, and 1 Black.