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Measuring the Impact of Unique Entry-Level Instructional Course Modules Designed to Inspire Computer Science Interest

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Abstract

Recent research regarding university student perceptions of "Computer Science" as a field of study and their motivation to pursue such studies as a career opportunity reveal student misconceptions and lack of motivation. Many students report that they regard the study of computer science as narrowly equivalent to "programming". Moreover, many are not consistently provided the opportunity to realize the true impact of the field within their entry-level courses since these early courses tend to focus on programming and syntax skill development. It is not until they are in their upper-level courses that they gain a broader understanding and by then, many of them have already left the field. It is hypothesized that this lack of clarity of the field at an early point in students' academic career, coupled with the perception that the curriculum is largely irrelevant to their lives, has impacted the retention rates of computer science majors in the first two years of their academic study programs. This paper will report on a preliminary stage of a comprehensive project effort that aims to improve retention rates for computer science students in their entry-level courses through the development of course modules intended for inclusion in their entry-level curriculum. The theoretical basis for these modules will be reviewed and the design framework for the development of these models is discussed. The aim of these models is to highlight the difference between Computer Science and Programming, to show the relevance of Computer Science in recent advances in various fields, and to inspire students to appreciate Computer Science and the role of algorithms in our daily lives. The modules will cover various topics about the role of CS in cyber warfare, understanding biology, electronic voting, etc. In subsequent work, these modules will be launched as part of a mixed methods study to determine their effectiveness as compared to a control group not learning through these models and the impact of those modules on the retention rates of Computer Science majors.

1. Introduction

The President's Council of Advisors on Science and Technology's (PCAST) recent report [1] predicts that the U.S. workforce's supply will be one million short of the demand for graduates in science, technology, engineering and mathematics (STEM), but less than half of those who enter U.S. colleges to pursue majors in STEM persist to graduation. Thus, there is significant demand for and need to retain STEM majors. This issue affects the field of Computer Science (CS) dramatically, and in particular, as related to the declining participation of women in the field. According to a 2013 report by the National Science Foundation [2], Computer Science as a field continues to see a drastic decline in the percentage of women participating in the field. Women slipped from holding 37% of all Computer Science bachelor's degrees granted in 1984/1985 to only 22.3% in 2011. This concern is recognized at the highest levels of our nation, and in January 2016, a new Presidential initiative called, "Computer Science for All" was announced. The goal of this focused attention is to empower all American students to learn computer science and to be supported to develop strong computational thinking skills needed to be creators in the digital economy and active citizens in the world [3]. Our economy is rapidly shifting, and both educators and business leaders are increasingly recognizing that computer science is a "new basic" skill necessary for economic opportunity and social mobility.

2. Background- College of Science and Engineering Quantitative Study Findings:

A self-study at Texas State University was conducted as part of the foundational research for an NSF award [4]. In 2012, STEM majors constituted about 7.4% of the overall undergraduate student population at Texas State (2,177 of 29,458). About 30% of those STEM undergraduates were Hispanics and African Americans and 16% were females. The student retention rates in every STEM field were analyzed and certain factors were considered as predictor factors such as ethnicity, gender roles, and student grades in critical courses. The goal in Computer Science is to improve the overall retention rate and increase the current percentage of women to 20% (based on a 25% increase goal across STEM disciplines), while ensuring are well integrated in their communities. Bandura [5] ties the concept of persistence as a manifestation of motivation, while Graham et al [6] view motivation as a driver of student engagement. Self-efficacy or confidence is one among several constructs underlying motivation. Programs that have been successful in improving the persistence of college students in STEM deploy three interventions, which include: 1) early research experiences, 2) active learning, and 3) membership in STEM learning communities.

3. Literature Review

Strategies to improve knowledge retention and student interest in Computer Science

Problem-based Learning (PBL) is an instructional model that may prove a good fit for computer science education due to the problem-solving basis that is also a quality shared with the nature of many STEM careers. Problem solving skills are also emphasized as cross-disciplinary skills and are embedded within mathematics and science learning standards for students at various academic levels. Problem-based learning is generally composed of two parts: a question or a problem and the students' arrival at a solution or a way of adapting to the problem. PBL allows the instructor to encourage their students to work in cooperative learning groups where they examine the problem, research, discuss, analyze, and produce tentative recommendations, explanations, or solutions [7]. The National Science Education Standards and Benchmarks for Science Literacy [8] call for a learning environment that is student centered and engages students in asking their own questions and designing experiments to solve problems. They also call for students to make physical system models that demonstrate their learning and understanding [9, 10]. PBL as an instructional practice meets these objectives and can result in a novel curricular approach that include flexibly structured activities and learning objectives around distinct learning standards in mathematics, science, engineering, or computer science.

Research also indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners [11]. Recently, there has been a particular interest in finding the overlap between engineering education and science, mathematics, and even the social sciences. While there is much research on the value of active learning, project based learning, and use of inquiry-based methods in the classroom, some researchers [12] argue for diversifying the learning experience and balancing both traditional lectures with active learning. In other research related directly to the field of computer science education, authors report on the best practices that allow for successful scaling of gender diversity initiatives in computer science education. They argue that universally-targeted, high leverage initiatives are the most important [13].

4. Intervention Description- Redesigning critical computer science (CS) classes through the integration of contextual and special interest modules

In a supporting foundational self-study, the retention rates of students in critical Computer Science courses were examined. At Texas State University, these are CS1428 (Foundations of Computer Science I), CS2308 (Foundations of Computer Science II) and CS3358 (Data Structures). It was revealed that the majority of declared undergraduate CS majors who leave the field do so in their first two years. One of the goals of this effort is to revise introductory CS courses by adopting course modules containing paradigms focused on providing the students with the CS big picture, familiarizing students with computational thinking, data-driven analysis, and multidisciplinary approaches early in their careers in contrast to the traditional expository instructional methodology currently prevalent in these courses. The modules are designed to be stand-alone mini-lectures that describe how CS is relevant in other disciplines/fields such as cyber warfare, biology, electronic voting, epidemics, etc. These modules would be supported by class projects that reinforce such paradigms. Teams of faculty in the STEM Faculty Learning Community will develop course modules in collaboration with CS faculty who coordinate entry- level classes.

5. Study Methodology

This study is composed of two efforts: (a) developing the intervention- the course modules that will be integrated into particular introductory computer science classes and (b) studying the impact of those modules upon students' perceptions of computer science through surveys.

In the first effort, it has been reported that students who leave computer science often lack a clear idea of what computer science is [14]. They are exposed to the field early in their academic careers through a series of introductory courses that focus on programming and syntax. This limited view is imparted to the students due to the focus on programming and to projects that do not necessarily require that students attempt to see and understand the big picture of CS and how this content is relevant in their lives. Such assignments do not provide students with a good service model. This topic should be presented earlier in the class so that students – when faced with programming assignments – realize that programming is just one element of Computer Science! Towards that end, a series of course modules have been developed to serve as the intervention that can be utilized to study the impact upon students' academic and affective changes.

One module developed introduces Computer Science as a field by making it clear that CS is not equivalent to programming by showing how CS can be studied without even using a computer! Certain activities are conducted in class in supporting the idea of CS as a problem-solving field. For example, in one activity a number of students are asked to shake each other hands one time. Soon they realize that it may not be efficient to do this in a random way, as each person would have to track every other person. This problem can be solved neatly by having two queues (say A and B) in which A has initially one person and B has the remaining ones. The first person in queue B would then shake their hand with the person in queue A and then joins queue A. This process is repeated until all the students are in queue A. Other class modules focus on how CS content is relevant to the real world.

5a) Developing the Intervention-Sample Module (Cyber warfare): In this module, the students are introduced to how modern social infrastructure is now more connected than ever with the use of information and communication Technologies and the recent advances in the fields of Internet of Things and Cyber-Physical Systems. Then, the students are invited to think about "what can go wrong with a connected infrastructure?" Students should be able to see how cyber-attacks on modern societal infrastructure are very different from regular attacks/malware/viruses that target computers and networks. The module then describes Stuxnet, the virus that targeted the Iranian nuclear program. Towards the end, students are invited to think about smart cities and what implications "attacks" would have on transportation, power-grid and other utilities.

Other modules will focus on biology, social networking and big data analytics. In the second effort, a survey has been developed to assess the impact of the interventions through tracking the progress of students who received the redesigned components. Their perceptions were compared to other students who did not receive the modules. The survey is adapted from validated Computer Science Attitude Survey reported in [15]. The survey is composed of 35 Likert questions in 3 main groups: (1) what is Computer Science, (2) relevance of the content, and (3) integration in the field. Demographic information was also acquired to draw general conclusions. Since it is typical to have many sessions of the same introductory classes, results can be drawn about the effect of those modules by comparing the perceptions to the students received the modules versus those who did not.

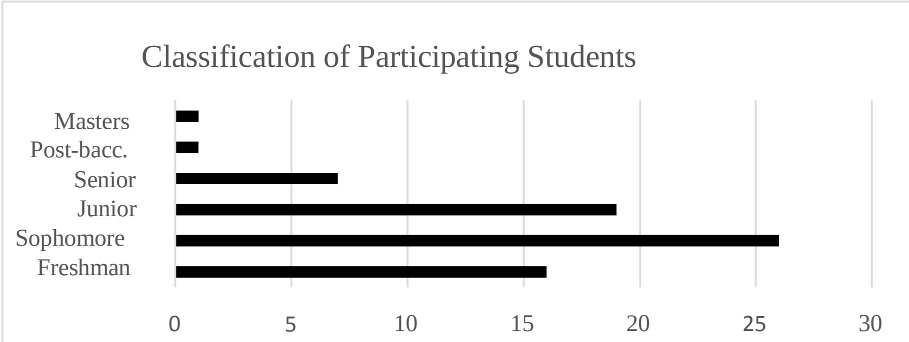
5b- Studying the Impact of the Modules: Pilot Data

The course entitled, "CS1428" is the first introductory class for CS majors and thus is a course that serves hundreds of students per semester. It is one of the target classes for interventions. In fall 2015, there were about 9 different sessions of this class taught by 6 instructors. Two course modules were delivered to one session of CS1428 and the following week the students received the survey and the results were compared to the survey results from students who did not receive the modules (under the same instructor and different ones as well). All surveys were conducted within a10 day window around the end of November. In one module, the focus was on Computer Science big picture and the other focused on cyber warfare (as explained above in details).

Another aspect that was not reflected in the results was the amount of interest the student developed from these modules. The students approached the faculty who delivered those modules after class and described their fascination with content of the modules and how informative the talk was. The students reported their feedback to their instructor who invited the faculty to deliver those modules again in the spring semester. One important goal is to present those results to the instructors and have them incorporate those modules in their classes.

6. Student Participants

This study was conducted during one semester. The participants are the registered university students who are enrolled in the target Computer Science courses discussed earlier who provided consent to participate. Seventy students participated in the study by attending a semester of instruction (some with the intervention modules and some without). These study participants completed fully the survey. Their demographics are shown below:



	Freshman	Sophomore	Junior	Senior	Post-bacc.	Masters
Freq.	16	26	19	7	1	1

Figure 1: Classification of Student Participants

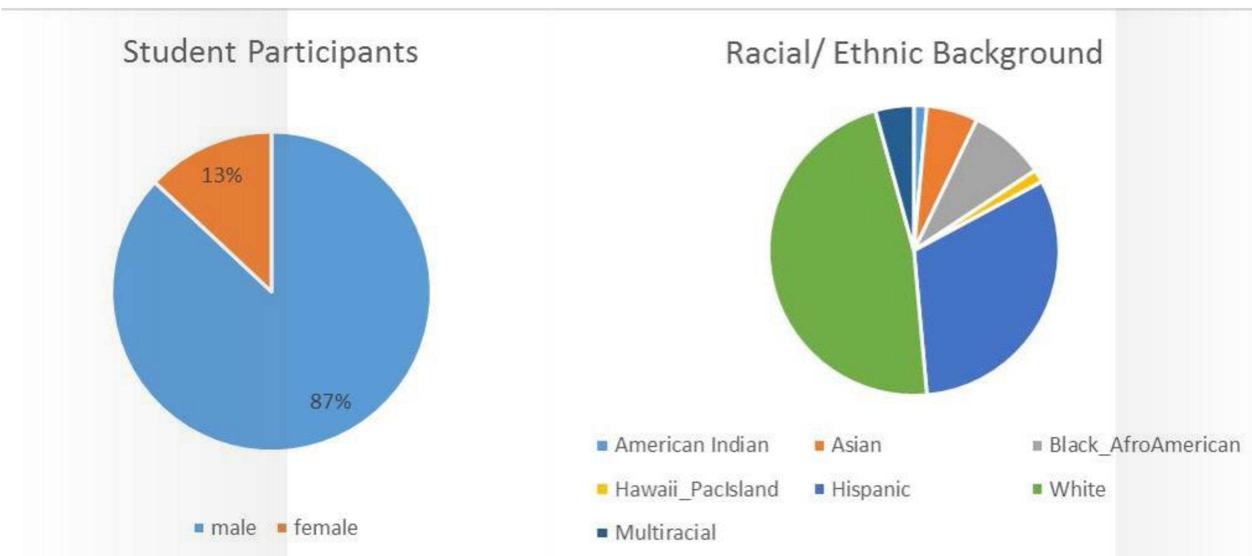


Figure 2: Student Demographics

7. Results from the Pilot Implementation

One of the hypotheses of this study is that an instructional intervention, such as the high- context computer science modules presented, can support student learning and motivation. By analyzing the student responses on the computer science survey, a two sample t-test is run/calculated to help answer the question and identify group responses that stand out. The driving research question in this study was, "What kind of difference is there in the survey responses regarding attitude, awareness, and understanding in the field of Computer Science by students who receive instructional intervention versus those students who received the instruction without the intervention." An additional question sought to identify if the differences seen here likely reflected real differences in the entire population of students represented by the study sample, so appropriate statistical tests were used.

The following summary statistics show that there were significant differences in several key survey questions between groups of students who received the intervention of the special contextual modules versus only the traditional course content without the modules. Mean difference between the two groups—with and without modules—is statistically significant at p < .05 and p < .01 levels as shown in Tables 1 and 2.

Table 1: Difference in mean for students with and without modules

Survey Question	Mean Difference	t score
Computer Science empowers our citizens	0.3333*	1.8439
Computer Science is all about problem solving	0.3810*	1.9432
Computer Science is a worthwhile and necessary subject	0.4286**	2.1767
I see Computer Science as a subject I will rarely use in my daily life	-0.3929*	-1.7261
Taking Computer Science courses is a waste of time	-0.4048**	-2.3252

* and ** indicates statistical significance at *p* < .05 and *p* < .01, respectively.

Table 2: Mean values for students with and without modules

	Mean Values		
Survey Question	Module	No Module	P-value
Computer Science empowers our citizens	4.3333	4.0000	0.0696
Computer Science is all about problem solving	4.5238	4.1429	0.0561
Computer Science is a worthwhile and necessary subject	4.4286	4.0000	0.0330
I see Computer Science as a subject I will rarely use in my daily life	1.7857	2.1786	0.0889
Taking Computer Science courses is a waste of time	1.3810	1.7857	0.0231

Scale: 5 = strongly agree, 4 = agree, 3 = neutral, 2= disagree, 1 = strongly disagree

8. Conclusion and Future Work

Driven by the stated overarching goal of increasing retention rates in Computer Science, this paper discusses the ongoing efforts to inspire students through the development of various course modules. The modules are designed to provide students with the big picture of Computer Science and demonstrate how CS is relevant in various aspects of our shared lives. A pilot study was conducted and the resulting data -- presented from the first semester of interventions -- has shown that students' perceptions of self, of career awareness, and of deeper understanding and caring of the field are significantly altered when these students participate in an Introduction to Computer Science course that utilizes the the new redesigned modules. Future work will analyze the impact of additional modules and will compare differences measured in student learning when comparing groups of students that are taught by different instructors.

Acknowledgments

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Appendix

COMPUTER SCIENCE PERCEPTION SURVEY

Adapted from the validated Computer Science Attitude Survey reported in Wiebe, E., Williams, L., Yang, K., and Miller, C. (2003). Computer Science Attitude Survey. Technical Report, North Carolina State University.

COMPUTER SCIENCE PERCEPTION SURVEY

Directions

On the following pages are a series of statements.

1. Read each statement.
2. Think of the extent to which you agree or disagree with each statement.
3. Mark your response.

Please remember:

- There are no right or wrong answers. Don't be afraid to put down what you really think.
- Don't spend a lot of time on any one item. Move quickly!
- Complete all of the items.

Respond to the following questions on the answer sheet, using the following scale:

1. Strongly agree
2. Agree, but with reservations
3. Neutral, neither agree nor disagree
4. Disagree, but with reservations
5. Strongly disagree

---

1. **I have a clear idea of what Computer Science is.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
o	o	o	o	o

2. **I joined/would join computer science to make money writing code.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
o	o	o	o	o

3. **Computer science can help us understand Biology.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
o	o	o	o	o

4. **The field of Computer Science plays an important role in the safety of our nation.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
o	o	o	o	o

5. **Computer Science can save lives.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
o	o	o	o	o

6. **Computer Science empowers our citizens.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
o	o	o	o	o

7. **Computer Science is about programming a computer.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

8. **Computer Science is all about problem solving.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

9. **Some CS problems can never be solved.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

10. **How well you solve a problem is not as important as solving the problem in the first place.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

11. **Computer Science is more about problem solving than programming.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

12. **One can do well in Computer Science without programming or a computer.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

13. **I'll need programming for my future work.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

14. **I study programming because I know how useful it is.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

15. **Knowing programming will help me earn a living.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

16. **Computer science is a worthwhile and necessary subject.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

17. **I'll need a firm mastery of programming for my future work.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

18. **I will use programming in many ways throughout my life.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

19. **Programming is of no relevance to my life.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

20. **Programming will not be important to me in my life's work.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

21. **I see computer science as a subject I will rarely use in my daily life.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

22. **Taking computer science courses is a waste of time.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

23. **In terms of my adult life it is not important for me to do well in computer science in college.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

24. **I expect to have little use for programming when I get out of school.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

25. **I feel I am a part of a larger Computer Science community.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

26. **I have friends in the field of Computer Science.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

27. **Working in the field of CS has a lonely experience for me.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

28. **I have access to knowledgable people who I can discuss CS problems with.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

29. **I have access to mentors in CS when I need them.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

30. **There are CS organizations that I'm excited to join.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

31. **I don't know many people who studied CS.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

32. **Computer science experts work alone.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

33. **I would trust a woman as much as I would trust a man when it comes to solving CS problems.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

34. **It makes sense to have more males than females in the field of Computer Science.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

35. **Females are as good as males when it comes to programming.**

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
○	○	○	○	○

Student ID: ____________________

Major:

Computer Science	Engineering	Other
○	○	○

Class Standing:

Freshman	Sophomore	Junior	Senior	Other
○	○	○	○	○

Ethnicity/Race [select all that apply]:

White	Hispanic or Latino	Black or African American	Native American	Asian / Pacific Islander	Other
○	○	○	○	○	○

Sex:

Female	Male
○	○

Are you a first generation college student?

Yes	No
○	○
