Mitigating the STEM Crisis through Enhanced Online Learning

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***Abstract* – According to the U.S. Department of Commerce, Economics, and Statistics Administration, in 2010 7.5 million people were employed in science, technology, engineering, and mathematics (STEM) jobs and accounted for 5.5 percent of the workforce. The report also stated that these occupations are projected to grow at a rate of 17.0 percent outpacing non-STEM jobs which are projected to grow only 9.8 percent. However in 2012, despite there being nearly 14 million unemployed people in the U.S., American companies could still not find workers skilled enough in math and technology to fill an estimated 3 million permanent job openings. The lack of trained skilled STEM workers has often been called the STEM Crisis. There are many researched reasons some argue that if there really is a STEM Crisis, why it exists. However, much of the traditional reasons, while still very valid have given way to reports that academic unpreparedness and lack of STEM literacy may be in part the cause for the shortage of STEM workers who possess a broad range of competencies and experiences. The response to this challenge has become the focus of many states, encouraging partnerships and collaborations between colleges/universities, K-12 schools, and public and private sectors. The aim of this paper is to present an effort to abate the STEM crisis through restructuring content delivery in an introductory computer science course taught a two-year institution. The paper presents the context in which the work is framed, the course design and delivery of the enhanced online learning experience, results from the study, limitations and future work.**

Keywords – Complete College America; enhanced online learning experience; learning content management system; STEM; undergraduate computer science education

I. INTRODUCTION

According to the U.S. Department of Commerce, Economics, and Statistics Administration, in 2010 7.5 million people were employed in science, technology, engineering, and mathematics (STEM) jobs and accounted for 5.5 percent of the workforce [1]. The report also stated that these occupations are projected to grow at a rate of 17.0 percent outpacing non-STEM jobs which are projected to grow only 9.8 percent [1]. The report further stated some of the characteristics of the STEM workforce which include that they earn on average 26 percent more than their non-STEM counterparts; more than two-thirds have at least a college degree; and, that they are less likely to experience joblessness when compared to their non-STEM counterparts [1]. Moreover, for women entering into STEM careers, they are likely to earn 33 percent more than women in other occupations [1]. Consequently, these statistics paint an advantageous portrait of why more students should choose STEM disciplines in college and why so much emphasis has been placed on STEM education. However, a common theme at the *U.S. News & World Report* STEM Solutions 2012 Leadership Summit in Dallas, Texas, was that despite there being nearly 14 million unemployed people in the United States, American companies could not find workers skilled enough in math and technology to fill an estimated 3 million permanent job openings [2]. The lack of trained skilled STEM workers has often been termed as the STEM Crisis.

The STEM crisis can be likened to the software crisis of the late 1960s and 1970s, in which software had to "catch up" to its more complex and powerful machines, thereby making informal software development no longer feasible. As a result, software engineering brought formal processes, methodologies and accountable to improve the quality of software being developed. Similarly, in the case of the STEM Crisis, formal processes are being developed and implemented to improve the quality of students/workers being trained for and entering into STEM-related careers. However, just as the answers to solving the software crisis was complex, understanding why the STEM Crisis exists and how to mitigate it is as well.

There are numerous researched reasons as to why some argue that there are not enough skilled STEM workers. For example, according to The New York Times' Christopher Drew, studies note that approximately 40 percent of students who choose to pursue a STEM area either switch their major in college or do not graduate at all [3]. This statistic, as stated by Drew, is twice the combined attrition rate of all other majors [3]. While others suggest that societal stereotypes, environmental and cultural factors, a lack of visible role models, different interests and experiences, are some of the reasons that students do not choose STEM [4]-[7].

Yet, according to the National Math and Science Initiative, a public-private partnership led by private donors and U.S. corporations, it is the declining number of students who are prepared to take rigorous college courses in science and math and who are trained for careers in those fields that has fueled the STEM Crisis [8]. ACT, Inc. reported that in 2011, 45 percent of U.S. high school graduates were ready for college-level math while only 30 percent were ready for

 ISBN: 978-1-61208-328-5

college-level science [9]. Consequently, for the U.S. to regain its competitive edge states are developing and implementing strategies to improve college-readiness especially in areas that depend on science and mathematics skill sets. Moreover, states are also investigating ways in which to improve access and student success once students enter the halls of academia. This paper focuses on one strategy to improve student success by restructuring content delivery through and enhanced online learning experience introduced in a traditionally taught introductory computer science course taught at a two-year institution.

The paper is organized into the following sections. Section II introduces the Complete College plan, an initiative undertaken by states to increase the number of students completing and earning college degrees or certificates and in specific areas that will help strengthen the U.S. economic prowess. Sections III and IV introduce the environment in which the study was conducted and present the enhanced online learning experience. Sections V and VI present the results and discussion from the study. While Section VII presents limitations, challenges, future work and concluding thoughts.

II. The Complete College Plan

A. Complete College America

In response to the concern that the U.S. is lagging behind other countries in its production of college-degree holders, Complete College America emerged in 2009 as a national non-profit organization whose mission is to work with states to increase the number of Americans with career certificates or college degrees [10]. Since its inception, 34 states, including the District of Columbia have become Alliance members and are now participating in working to significantly increase the number of students who are successfully completing college.

To become a member of the Alliance, the state's governor in partnership with its colleges and universities pledge and work together to meet the Mission of Complete College America [10]. More specifically, when a state becomes an Alliance member it makes college completion a top priority and commits to do the following [10]:

- Set completion goals
- Collect and report common measures of progress
- Develop action plans and move key policy levers

B. Complete College Georgia

The state of Georgia is an Alliance member and has adopted the Mission of Complete College America, which includes that by the year 2020, 61 percent of young adults will hold a college certificate or degree. Georgia also notes that in order to improve the state's economy that another 27% of Georgians must join the already 34% of the states' population who currently hold an associate's degree or higher [11]. To meet this goal, not only must the colleges and universities in Georgia enroll more students, but they must retain the ones currently enrolled and remove barriers that impact student success.

In Georgia there are two public systems, the University System of Georgia (USG) and the Technical College System of Georgia (TSG). In 2011, leadership from the two systems met along with state leadership and representatives from the business community to receive a charge from the Governor on ways to change the higher education funding formulas to incentivize degree completion [12]. The result was an Articulation Agreement between the USG and the TSG. The Articulation Agreement proposed to:

- Create new forms of collaboration and accountability among organizations responsible for or reliant on higher education
- Continue to work with the Georgia Department of Education to increase the number of college-ready students graduating from high school
- Reevaluate and envision anew the performance of completion-related aspects of higher education

More specifically, approaches to improve low completion rates included [11]:

- Building and sustaining effective teaching
- Exploring and expanding the use of effective models
- Distance education
- Adult and military outreach
- Implementation of STEM initiatives

C. Georgia Perimeter College

Georgia Perimeter College (GPC) is a two-year institution located in the Atlanta-metro area, part of the 35-member schools of the USG. GPC offers Associate degrees in Arts, Sciences and Applied Sciences [13].

GPC typically hosts the largest freshman and sophomore enrollments in Georgia, making it the top producer of transfer students to 4-year institutions within the state of Georgia. It has five campus locations and services approximately 23,000 students. The number of students choosing one of the STEM disciplines is roughly 10 percent [14]. The average age of the student population is approximately 26 years old and 59 percent of the students are enrolled as part-time students, meaning that they take less than 12 credit hours during the semester [15]. Further, roughly 10 percent of the students take all their classes online [15].

In response to Complete College Georgia, GPC created the Office of STEM Initiatives. The mission of the Georgia Perimeter College Office of STEM Initiatives is to promote student access and to improve student success in the STEM disciplines. The goals of the office are to:

- Increase the success rate of students in STEM "gatekeeping" courses
- Provide educational opportunities and support for students choosing STEM disciplines as a major

- Deepen student and faculty engagement in college-wide STEM activities
- Support, connect and strengthen collaborations to advance STEM preparation for P-20 students and faculty
- Develop and support exemplary practices and policies in STEM education at the 2-year college level

To encourage faculty members to engage in activities that improve student success in STEM-related areas, the Office of STEM Initiatives developed the STEM Faculty Mini-Grant Program. The goal of the GPC STEM Faculty Mini-Grant Program is to support faculty who engage in innovative research-based projects that:

- Restructure current instruction delivery models
- Develop new models for building and sustaining effective teaching
- Impact student learning and performance through enhanced learning experiences

The next section describes the author's activities developed to meet the goal of increasing the success rate of students in STEM "gatekeeping" courses with a specific emphasis on CSCI 1300 – *Introduction to Computer Science*. CSCI 1300 is the first course for students interested in pursuing a computer science career and normally has a high attrition rate.

III. Introduction to Computer Science

A. Course Description

CSCI 1300 – Introduction to Computer Science is designed to provide students with an overview of selected major areas of current computing technology, organization and use. Prerequisites are exit or exemption from all Learning Support, English as a Second Language (ESL) requirement and successful completion of College Algebra [16]. For computer science majors, the course is a prerequisite for successive courses within the program of study. For other majors, the course meets the requirements of the common core in the area of science, mathematics and technology from which students must choose.

B. Topics Covered

Since the course is a commonly taught course, all students are presented with the following topics [16]:

- The history and vocabulary of computers
- Problem-solving, algorithms and algorithm efficiency
- Data representation and storage
- Computer hardware and software concepts
- Computer networks and information security
- Programming concepts and problem-solving
- Application software and Databases
- Social and ethical issues

C. Learning Outcomes

The learning outcomes are designed by the course curriculum committee. It was decided that by the end of the course, a student should be able to [16]:

- Discuss the history of computing.
- State the methods by which data is represented and stored in a computer's memory.
- Recognize and understand the fundamental hardware components of a computer system.
- Recognize and understand the fundamental software components.
- Understand the concepts of current communication technologies.
- Understand basic networking and information security.
- Recognize and understand social and ethical issues involved in computer use.
- Analyze a basic real world problem and solve it with a computer program.
- Understand and write algorithms using fundamental computing concepts.

IV. Enhanced Online Learning experience

A. Participants

As previously stated the course is designed for and utilized by students who have chosen one of the STEM disciplines as a major. At GPC, the STEM majors are Biology, Chemistry, Computer Science, Engineering, Geology, Mathematics and Physics. During the fall 2013 semester, 28 students enrolled in the course; however, seven of the students withdrew prior to the midpoint of the semester and therefore the number of participants in the study is 21. Of the 21 students, the majority was computer science majors, 53 percent, followed by 33 percent engineering majors, 5 percent physics majors and an additional 10 percent had not declared a major in one of the STEM areas. Moreover, the class consisted mostly of sophomore students, 62 percent. The average age of the students was 25 and the class was comprised of 90 percent male and 10 percent female. All students were associated with a "home" campus, meaning that none were identified as online students.

B. Procedure

Researchers note that there has been a dramatic shift in the way in which students learn [17]. Technology supported learning provides students with an opportunity to view online situations and examples that help to aid the learning process. Additionally, technology supported learning has been shown to be beneficial to students who are visual learners rather than auditory learning [18]. It has been noted that students process visual information 600,000 times faster than text, and visual aids can improve learning by 400% [19]. However from a delivery perspective, technology supported learning provides a semi-permanent resource which allows students to re-visit the clips, thereby increasing the potential to develop greater understanding of the material.

Consequently, it was decided that the PowerPoint slides that the author typically used in class, would be modified to include an enhanced online learning experience. The slides were revised to include voice narration on the lecture topic, narrated problems usually solved in class and educational videos. Students were encouraged to view the lectures prior to coming to class. Unlike the traditionally taught modules where the lecture slides were covered in class as part of the class period, the material developed for the enhanced online learning experience was to be viewed out of class so that the class period could be utilized for answering questions and working practice problems.

Both the traditionally created lecture slides and the enhanced online lecture material were posted in the Colleges' Learning Management System, Desire2Learn (called iCollege by GPC). The author chose to post the material in iCollege because all enrolled students have access to it and it has features that allowed the instructor to gather statistics on who viewed the slides and for how long.

It was decided that the programming concepts and problem-solving module would be best suited for the enhanced online learning experience. The author chose this module because it was the implementation of the theoretical concepts learned earlier in the sixteen week semester. Moreover, the author thought that the students would benefit more from the hands-on experience and practical application associated with the module as compared to previous topics. Table 1 presents the order in which the modules were presented and the associated assessment.

TABLE 1. CONTENT DELIVERY

Week	Module Topic and Number	Assignment Number
1	1- Introduction to Course and History of Computing	1
2	2 - Representing Algorithms	2
3	3- Attributes of Algorithms	3
4	***In Class Exam #1***	
5	4 - Binary Numbering System	4
6	Boolean logic and gates	
7	5 - Components of a computer system	5
8	6 - Basic networking	6
9	***In Class Exam #2***	
10	7- Programming Concepts	7
11	Programming Concepts	
12	Programming Concepts	
13	***In Class Exam #3***	
14	Application Software	
15	Ethical Issues	
16	***Final Exam***	

V. RESULTS

To determine the effectiveness of the enhanced online learning experience, the following data were collected:

- Average viewing time spent on all lectures
- Number of viewers per module
- Student performance on assignments
- Student performance on exams
- Results from a student survey

A. *iCollege Results*

The results revealed that on average, students spent approximately 24 minutes and 54 seconds reviewing the lectures posted in iCollege. There were between two and six lectures created per module. This number varied depending on the complexity of the topic. Figure 1 presents an overview of the viewing time spent per module.

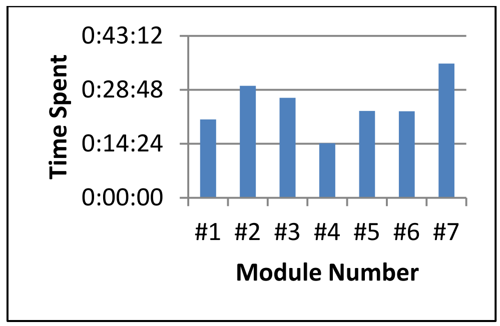

Figure 1. Average time spent per module

The results also revealed that of the 21 students who completed the course, the number of viewers per module was roughly 18. Figure 2 shows the average number of viewers per module.

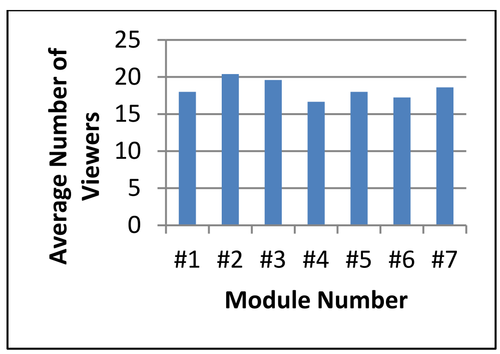

Figure 2. Average number of viewers per module

B. *Student Assessments*

The author also wanted to assess the impact of the enhanced online learning module on student performance. After the completion of a module, an assignment was given. Figure 3 shows the results of student performance according to the module. Module #7 is the enhanced online learning experience.

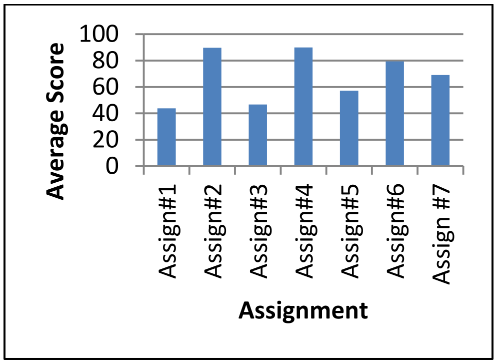

Figure 3. Average Score per Assignment

Figure 4 shows the results of student performance on the three exams administered, with the only content for exam #3 being that taken from the enhanced online learning module.

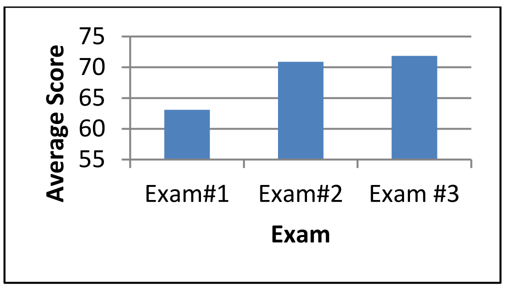

Figure 4. Average Score per Exam

C. Student Survey

Lastly, a brief survey was distributed to the students after the completion the enhanced online learning module. The purpose of the survey was to get a better understanding of students' perception on the inclusion of future enhanced learning modules in the course. Figure 5 presents the results.

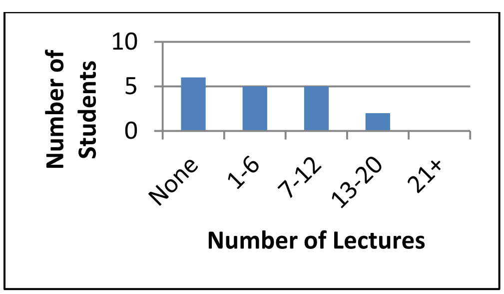

Figure 5. Desired Number of Enhanced Online Lectures

Additionally, the author had previously proposed a hybrid course based on the flipped classroom model. As part of the survey, the author also asked if students would consider enrolling in a hybrid course for CSCI 1300. Figure 6 presents the results.

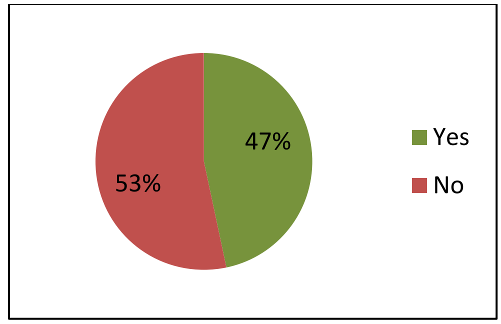

Figure 6. Hybrid Course Results

VI. DISCUSSION

The results revealed that students spent on average 35 minutes and 50 seconds on the enhanced online learning module which is roughly 12 minutes and 47 seconds more than the average time spent of 23 minutes and 3 seconds, viewing the traditionally created lectures posted in iCollege. While this is not a substantial difference, it is consistent with what the author anticipated, which was that students would spend more time viewing the enhanced online learning module because the material covered would not be face-to-face as with the other modules. Furthermore, this result shows that although it has been reported that on average students' attention span is around 8 to 10 minutes long during a traditional long [20] , students will engage in enhanced online lectures for a longer period of time. However, it was surprising to the author that the average time spent viewing the enhanced online learning module was not higher. But because this module was the implementation of module #2, algorithmic development, which had the second highest recorded viewing time, the author believes that the students felt more comfortable with learning the syntax of C++ because many of theoretical concepts had been previously covered (i.e., selection statements, looping, and evaluation of expressions).

The student performance data on the assignments also showed no substantial difference between the face-to-face modules taught and the enhanced online learning module. However, the exams scores show a remarkable difference and indicate an increase of knowledge from exam #1 to exam #3. When asked, students indicated that they felt more comfortable and better prepared to take exam #3 as compared to exams #1 and #2. However, the author considers the result from this data inconclusive, because there are many variables that may have impacted student performance which include, the technology supported learning of the enhanced online modules as well as students' self-efficacy.

Lastly, the student survey revealed that while some students wanted to include enhanced online lectures as part of their learning experience, others did not. This result can also be seen in the response to the question on whether students would want to take CSCI 1300 as a hybrid course. Fifty-three percent of the students stated that they would not

ISBN: 978-1-61208-328-5

take the course as a hybrid offering, while forty-seven percent stated that they would. The author finds this result to be one for future investigation as hybrid courses offer both the face-to-face component blended with the flexibility of online learning. Moreover, because 59 percent of GPC students are enrolled part-time and roughly 10 percent of the student population takes all their classes online, the author anticipated that an overwhelming number of students would enroll in a hybrid computer science course. Yet when asked, students expressed concern of "having to learn this difficult material on their own" and they also wanted a traditional environment because "this is my major and I want to be prepared."

VII. CONCLUSION

The aim of this paper was to present the results from a study that investigated the restructuring of content delivery in an introductory computer science course to include an enhanced online learning experience. The results revealed there was no significant difference in viewing preference or student performance, which leads the author to question the impact and effectiveness of the enhanced online learning module. The study further revealed that when students were asked if additional enhanced online learning modules should be included as a part of the course, the responses were mixed. Students' concerns of "learning difficult material on their own" and not "feeling prepared" are validated in studies like those conducted by the Community College Research Center at Teachers College, Columbia University, of students enrolled in Washington State Community and Technical Colleges. The study found that the students enrolled in online classes were more likely to perform poorly and also less likely to complete their degrees and/or transfer to a 4-year institution [21].

However, there are some limitations to the study which impact the author's findings. The author notes that the use of PowerPoint, even with the enhancements made may have reduced the effectiveness of content delivery. Another limitation of the study is the point of introduction of the enhanced online learning module into the course. The restructured content delivery experience was introduced after the midpoint of the semester which may have influenced students' performance. For future work the author proposes to mix the delivery of content among modules, instead of between modules. Lastly, for future work, the author intends to introduce as a compliment to the learning experience, student-developed enhanced online lectures to investigate their impact on lecture viewing and performance.

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