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Enhancing Computer Science Program Through Revising Curriculum, Peer Mentoring/Tutoring, and Engaging Students in Undergraduate Research

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Abstract

The Computer Science (CS) program at Fort Valley State University (FVSU) has recently witnessed an alarming decline in retention rate and a slow progress toward graduation of its students. Additionally, the assessment results of computer programming courses and the ETS (Educational Testing Service) Field Exam (the official exit exam of FVSU computer science program) have revealed that CS students are not performing satisfactorily in computer programming subjects.

To address the above issues, we propose a three-pronged approach to enhance CS curriculum as well as the retention and graduation rates of computer science students at FVSU. This approach includes revising course curricula of all upper division courses to include at least one major programming assignment/project, implementing peer-to-peer tutoring/mentoring, and engaging students in interdisciplinary/multidisciplinary undergraduate research activities.

This project is currently work in progress and expected to have a positive impact on the curriculum of computer science program and all of its students from freshman to senior level. We anticipate that the project will enhance the curriculum of at least 15 CS (including 12 upper level division) courses, increase the passing rate of students in gate keeping courses by 30% or more and the graduation rate of normal completion time by at least 40%, and improve the performance of senior students in programming subjects of Exit Exam by at least 50%. The project could also serve as a model for computer science programs of other institutions facing similar issues.

Introduction

In recent years, there has been a rapid growth in computer/information technology industry and related services mainly due to expansion of cloud and mobile computing, artificial intelligence, and cyber security fields. This has generated a greater demand for computer programmers and information technologists in various sectors of the industry. In this regard, an acute need for software developers and computer programmers in the U.S. job market is forecasted in near future. According to the U.S. Bureau of Labor Statistics[1], "Employment of software developers is projected to grow [by] 24 percent from 2016 to 2026, much faster than the average for all occupations." Furthermore, according to Burning Glass researchers (http://burning-glass.com), approximately 50% of all high-paying jobs (>$58,000) require some level of computer programming skills. While computing and information technology fields are enjoying a rapid economic growth, the number of US students graduating from computer science (CS) and/or closely related fields has not kept pace with this growth due to high attrition rates in CS programs[2]. This problem is even more acute in minority serving institutions, particularly HBCUs as reported in New York Times[3] that the percentage of African American

students graduating in computer science and engineering was only 6% of all recent graduates. Thus, it is important for computer science programs, particularly in minority serving institutions, to revitalize curricula to emphasize more on computer programming, and establish/enhance student support systems that could help students overcome academic challenges and graduate on time.

The computer science program at FVSU, a unit of University System of Georgia (USG), has witnessed a recent up-surge in its enrollment numbers in spite of the institutional enrollment drop, which is coincident with the national trend and shows the growth potentiality of the program. While the program is currently enjoying a moderately good student enrollment, it is suffering from relatively low retention and graduation rates. For instance, the average retention rate over the period of 2013-2016 was approximately 50.4% and the average graduation rate over the same period was about 9 students per year. In fact, our program graduation rate has not been at a level that fully meets the standard of USG graduation rate. During the period of 2010 to 2013, the CS program graduation rate averaged about 7 students per year[4], which was lower than the minimum of 10 set by USG. As a result, the computer science program was flagged as a low producing program that could subject to elimination if it could not reverse this trend in a three-year period. Although from 2013 to 2016, the graduation rate has been improved to about 9 students per year, we still need to further improve it in order to fully meet the standard of USG.

Further, the assessment results of sophomore level programming and digital fundamental courses over the same period indicate that majority of students are weak in computer programming and problem solving skills related to computer logics. The results show that approximately 63% of students were able to score 70% or better on the assessment exams while only 29% of students were able to score 80% or better. In addition, the results of ETS exit exam over the past five years indicate that CS graduating students performed poorly (approximately 45% passing rate) in programming subjects of the exam.

Based on our informal student tracking data, students who fail twice in their programming, especially programming I, and digital fundamental classes (gate keeping courses) tend to withdraw, change their majors, or have a slow progress toward graduation. Furthermore, even students who do relatively well in these classes tend to lose their technical capabilities to tackle fairly large and complicated problems from concept to solution and then implementation using sound computer programming practices due to lack of sufficient practice in their upper division courses. This has been observed in the CS capstone course that requires students to design relatively large programs for various course projects. As a result, this could hinder their progress toward graduation as well as future success as software developers, computer programmers, and/or other information technology and computing professionals. Thus, it is critical to improve the programming skills of computer science students across curriculum particularly in all upper level (junior and senior) courses. To further enhance the overall quality of the CS program, it is also important to engage students in undergraduate research activities that could help retain high achieving students and enhance their knowledge and skills in various aspects of computing field, particularly programming.

To address the aforementioned issues, the CS program at FVSU recently submitted a grant proposal, which focused on curriculum revisions and establishing an academic support system that nurtures and retains students through mentoring, tutoring, and undergraduate research activities, to the Department of Education under Title III-Part B Program. The proposed project was accepted for funding for a period of 3 years (Oct. 1, 2017- Oct. 1. 2020) in September 2017. This paper describes the project goals, objectives, and expected outcomes as well as the steps taken to implement some of the project activities. It should be noted that the project is a work in progress and thus its impact on the students and our CS program could not be currently evaluated due to insufficient data. The effectiveness of the project will be measured annually by October of each project year. We are planning to present the assessment results of this project in a future article by 2020.

Goal Statement

The primary goal of this project is to enhance the retention and graduation rates of computer science students at FVSU through revising curriculum, implementing a peer-to-peer tutoring/mentoring, and engaging students in interdisciplinary /multidisciplinary undergraduate research activities. This goal is also fully aligned with the University mission that states "FVSU mission is to promote academic excellence for the improvement of the quality of life for the people it serves"

Statement of Significance

For the first time, the computer science program at FVSU is planning to conduct a major effort to improve and enhance programming knowledge and skills of its students while progressing through the program, enhance retention and graduation rates, and engage students in enrichment programs. The significance of this project is as follows:

1. Enhance the course curricula of all CS upper level courses (3xxx/4xxx) to reflect the most current trends in the field and to respond to the growing demand of job market for more trained graduates in the fields of programming and software development.
2. Increase the retention rate and progress toward graduation of CS freshman and sophomore students by using a peer-to-peer tutoring/mentoring approach in gate keeping courses, to help "at risk" students and thereby improve the overall success of the CS program. In this endeavor, we will be in close collaboration/consultation with the University Retention Center to utilize their experience to effectively and efficiently implement our tutoring/mentoring program that will be established for the first time for our CS program. It should be note that the positive impact of peer tutoring/mentoring has been emphasized in literature[5-9] particularly for students majoring in STEM fields. The tutoring/mentoring model used in project is similar to those described in references 6 and 7.
3. Engage students in undergraduate research activities to further enhance the quality of CS education at FVSU. Experience in undergraduate research is highly

desired by graduate schools and potential employers. The undergraduate research component of this project will prepare our CS students in real world problems and thereby enhancing problem solving, critical and analytical thinking, and programming and communication skills of students. The multidisciplinary feature of this program will be unique at FVSU and foster collaboration among faculty and students across different disciplines. This effort will be conducted in close collaboration with the FVSU Research Center.

4. Serve as a model for other CS programs, particularly those of HBCUs and other minority serving institutions that are facing the same problems.

The activities of this project could also have a very positive impact on recruiting high achieving students to our CS program. Once the prospective students learn about our strong curriculum in CS program, student support system, and opportunities for research activities, they would be more inclined to enroll at FVSU computer science program.

Contextual framework

The goal of this project can be achieved through the following objectives:

1. Enhance the CS curriculum of 12 upper level courses to include at least one major programming assignment/project.
   Performance Indicators:
   - During each year of the project, at least the curriculum of 4 CS courses of 3xxx/4xxx will be revised by September of the project fiscal year.
   - By April 2020, at least 70% of students will have a passing grade of C or better in the programming subject of computer science exit exam conducted by ETS.
2. Implement a peer tutoring/mentoring approach that supports freshman and sophomore computer science students in gate keeping courses in order to increase the retention rate by 20% (6.5% per project year) from the base of 50.4% [4], starting spring 2018.
   Performance Indicators:
   - By September of each project year, The retention rate is expected to increase by 6.5%
   - By April 2020, at least 50% of CS graduating students will have a grade of B or better in the programming subject of computer science exit exam conducted by ETS.
3. Integrate an undergraduate research program to involve at least 12-20 junior and senior computer science students during the last 2 years of project, starting fall 2018.
   Performance Indicators:
   - Involve at least 3-5 students per semester in interdisciplinary/ multidisciplinary research activities, starting August 2018 through spring 2020.
   - During each year of 2018-2020, at least 70% of students who participate in the undergraduate research projects will publish/present their research findings at national, regional, and/or local conferences as well as the FVSU Research Day.

Project Activities

Objective1 activities:

- Conduct a workshop for CS faculty to demonstrate the course curriculum revision by including programming assignments/projects. This activity was carried out at the end of fall semester 2017. During the workshop, we shared a template developed for programming assignments/projects with other CS faculty members. After reviewing the template and minor modifications to it, the faculty agreed to include a major programming assignment according to the structure described in the template for their upper level courses starting spring 2018 semester. In the template especial emphasis was placed on algorithmic solution methods, advanced data structures, object oriented programming, and common software engineering practices such as documentation, maintainability, and scalability.
- Every computer science faculty will develop at least a major programming assignment/project that requires the application of Java, C/C++, and/or Visual Basic/Visual C# for CS courses of 3xxx/4xxx. (work in progress)
- Incorporate the programming assignment /project as a part of course assessment instrument. (work in progress)

Objective 2 activities:

- Design a tutoring/mentoring manual which will be used by student tutors/mentors. This activity has been already accomplished. A tutoring/mentoring manual has been developed to outline the mission of the program, tutor/mentor responsibilities, qualifications, work expectations, "Tutors/Mentors Can and Tutors/Mentors Can Not", benefits of tutoring/mentoring, and suggested tutoring/mentoring techniques including possible problem areas. In the manual, a special emphasis was placed on maintaining an accurate log of students attending tutoring/mentoring sessions and regularly communicating with the course professors and project director about their tutoring/mentoring activities. To further enhance the communication between tutors and course instructors as well as to better familiarize the tutors with the students and class activities, the tutors would be required to attend 2 to 3 classes per week (maximum 3 hours/week) for the course(s) they tutor. The attendance in these classes would be considered as part of their tutoring load.
- Identify at least 5 qualified students for tutoring/mentoring task. These students have performed at least at a level of B or better in the gate keeping courses, have junior/senior standing, and have a GPA of at least 3.0. For spring semester 2018, we were able to recruit 4 qualified students to tutor Programming I and II courses taught in Java (Only, these two gate-keeping courses were offered in spring 2018). Two tutors were assigned to each course. Tutors would be working at least 10 and at most 15 hours/week for the duration of the semester. It should be noted that it was rather challenging to hire qualified tutors/mentors for this task mainly due to the fact that a number of qualified students have reservation about tutoring computer programming subjects.

- Identify students struggling in gate keeping courses. The students will be generally identified based on their class performance in these courses in an ongoing basis. However, an assessment quiz will be given to the students at the beginning of classes to help identify students who might need tutoring. Then the instructors of the courses will refer those students to the course tutors. As the classes progress, new students would be identified to participate in tutoring sessions based on their class performance. The course instructors would offer extra credit points to students who attend at least 90% of tutoring sessions and complete tutoring activities. This is an important incentive for students to attend tutoring sessions particularly for those who are struggling in these courses.
- Conduct a workshop for tutors/mentors at the beginning of each semester to train them in tutoring/mentoring skills in collaboration with the University Retention Program. This task was carried out for the tutors of spring semester 2018 in mid January. During the workshop, we went through the tutoring/mentoring manual, showed the location of tutoring center, and demonstrated a mock tutoring session with a student. This included how to greet a student and interact with them in a friendly and yet professional manner as well as how to interact with a difficult tutee.
- Hold bi-weekly meetings with student mentors regarding assigned tasks and progress.
- Conduct a summer workshop for CS faculty teaching the gate-keeping courses in computer science regarding peer mentoring / tutoring. During the workshop, faculty will design new assessment quizzes to be used to identify struggling students. Also, they will develop tutoring assignments for student tutors. The first summer workshop will be conducted in June 2018. Participating faculty will be compensated through the project funds for their time and efforts.

Objective 3 activities:

- Design undergraduate research projects and plans to be carried out by students involved in research. Some projects will be multidisciplinary that require collaboration with Agriculture faculty and students. These projects will include applications of image processing techniques to disease control and diagnostics for crops and trees. Other projects will be interdisciplinary and involve applications of computer vision and programming to control robots and unmanned aerial vehicles (UAV drones). The authors have extensive experience in leading and designing undergraduate research activities from previously funded projects.
- Select 3-5 high achieving junior /senior students for undergraduate research activities starting August 2018. These students will have at least a GPA of 3.0. The participating students will receive stipend through the project funds.
- Conduct a workshop for the selected students to provide information regarding research projects, planning, expectations, and professional presentations in collaboration with the FVSU Research Center.
- Submit the research findings of at least 3 students to pertinent national/regional/local student conferences (including FVSU Research Day) per year.

Dissemination of Project Results and Findings

To share our project experience in curriculum improvement, tutoring/mentoring practices, and undergraduate research project design methodology, a summer workshop will be conducted for at least 10 STEM faculty members from FVSU and nearby colleges in the third year of the project (2020). Further, at the conclusion of the project, we plan to publish a scholarly article regarding the project results and outcomes in a relevant academic conference/journal.

Project Evaluation

The project goals and objectives will be assessed by the achieved project performance indicators on yearly basis. Not only will the project investigators participate in the assessment, but also a project steering committee will be formed to help the investigators in the assessment process by providing feedback and suggestions to further enhance the ensuing project implementation plans. The steering committee members will be mainly from other STEM programs within the university and at least one member would be on voluntary basis from another educational institution or a private industry in the field of computing. The steering committee will be formed in August 2018.

Summary and Concluding Remarks

The project described here is expected to help alleviate the following problem areas in our current computer science program:

- Relatively low retention rate and slow progress toward graduation due to poor performance of freshman and sophomore students in gate keeping courses (computer programming and logic classes).
- Unsatisfactorily performance of senior students in programming sections of exit exam conducted by ETS and the programming projects of Senior Seminar (Capstone) class. This is partly due to the fact that most of current upper level courses do not require any substantial programming activities in the course curriculum in order to constantly engage students in writing efficient and logically sound computer programs.
- Retention of high achieving student due to lack of enrichment programs such as undergraduate research to further their academic experience.

We expect the establishment of peer-to-peer tutoring/mentoring center, the inclusion of programming assignments/projects in all upper level courses, and mentoring students in undergraduate research activities help enhance the overall quality of our CS program and specifically address the above problems.

It is also realized that the project sustainability beyond its funding period is important for having a successful CS program that is academically strong and also attractive to students. In this respect, we plan to make significant efforts during the course of the project to ensure the project sustainability by:

1. Developing one major elective course related to undergraduate research. After the project ends, students could take the course to participate in research and obtain credits towards graduation instead of receiving stipends.
2. Integrating tutoring/mentoring in the Internship course--a CS elective course. This will allow students to obtain credits towards graduation for his/her efforts as a mentor/tutor. Therefore, it could eliminate the requirement for stipends.
3. Developing and cultivating partnership which will be self-sustaining after the project funding ends. The partnership will include both academic institutions and industrial organizations. Building a partner-based approach to training and outreach will provide the additional resources important for program expansion and enhancement as well as better sustainability.
4. Seeking external sources of financial support by writing grant proposals to various public/private funding agencies.

The only component of this project that might require financial support after the project funding ends would be the student support system. After the project ends, it is expected that the university administration would be willing to invest in this program through available internal funds once they realize the effectiveness of the student support system in increasing retention and graduation rates of CS students as well as its positive impact on student recruitment to the program.

Finally, we anticipate that this project will enhance the curriculum of at least 15 CS courses (including 12 upper level division courses), increase the passing rate of students in gate keeping courses by at least 30% and the graduation rate of normal completion time by at least 40%, and improve the performance of senior students in programming subjects of Exit Exam by at least 50%.

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