Project Title: Piloting a mastery based learning approach in a lower-division computer science course

Faculty Submitting:

Rhonda Hoenigman
Faculty Director of Undergraduate Education
Department of Computer Science
ECOT 738
Rhonda.hoenigman@colorado.edu

Descriptive Title: Piloting a mastery based learning approach in a lower-division computer science course to address differential rates of student preparation and learning

Project description and rationale

In the first-year computer science courses, which include CSCI1300 – Introduction to Computer Programming in the first semester and CSCI2270 – Data Structures in the second semester, we consistently see students with different backgrounds and levels of preparation. Students who took programming in high school are often already familiar with basic computer programming concepts, which helps them absorb advanced concepts in both semesters more quickly than students who are new to programming. In addition to having different experience prior to the class, students also learn at different rates once they're here, and students who need more instruction than their peers can quickly fall behind in a large class.

In this project, we are proposing to develop a mastery based learning strategy for CSCI2270 to assess students' understanding of individual concepts and provide the additional resources they need to be successful. The strategy would be implemented in Spring 2018. Mastery-based learning is an educational approach that of supports a student fully understanding all concepts in a particular topic before advancing to the next topic. [1] This approach is different than our current education model where we have a fixed amount of time to cover a given amount of information, and then we test students on this material and move on. We fix the amount of time given to a topic and vary the amount of information a student learns. Unfortunately, in STEM courses, many of the concepts that a student might miss could be crucial pre-requisites for understanding future material. Instead, with mastery based learning, students are allowed to review and test on information as often as they need to in order to learn the material.

Due to the size of the CSCI2270 course (~600 in Spring 2018 semester), we are not proposing to implement all of the features of mastery based learning in one semester. We will still need to have deadlines for a given section, with students not receiving credit for material they had not learned. What we are proposing is to develop materials to scaffold students' understanding of concepts, which will then allow them to apply their understanding of those concepts. To demonstrate how this will be implemented, at the beginning of the semester each student takes an assessment test consisting of all the prerequisite information a student will need for the course. Then, at the beginning of the semester and based on this assessment, a student will be assigned a group of problems (mastery based learning). The first section of material to be covered will also be included in this assigned material. Concepts for a given week as well as the prerequisite knowledge will then be broken up into two-day increments of concept mastery. Students will receive a grade based upon concept tests given after each section of material, which they will be allowed to take continually until mastery has been achieved. This can be judged by getting 3-5 problems of the same type in a row correct. Periodically throughout the semester (perhaps every 3-4 weeks) a student will be required take another assessment that will provide an accurate and updated knowledge graph and the problems for the future weeks will be based upon this assessment.

In addition to the assessment, we will provide the additional instruction that students need to complete the assessments through online videos, short written explanations, and examples that cover a given topic. These resources will free up considerable classroom, recitation, and office hour time for deeper and more active learning. Instead of the course instructors and TAs spending time explaining or re-explaining core concepts, students will be able to go over this material at their own pace, as many times as they need to, and come to office hours if they have specific questions. This avoids using valuable classroom time for basic instruction, and allows for more complex or application-based discussions. These resources will enable students to build a firm foundation for later topics and future classes by improving comprehension and retention.

A crucial component of mastery based learning is a knowledge graph showing the concepts that the student should know to complete a given task, including both the pre-requisite concepts as well as the concepts that the assignment is designed to present. [1] A student's knowledge graph identifies the information a student knows in a given subject, and can be used to determine the body of instruction that they need to be complete in a given week. As part of this project we will develop a knowledge graph of all concepts currently required for all assignments in the class. We will then use the knowledge graph to design the instructional materials and assessments.

There are already several Data Structures videos available on YouTube showing core concepts. However, many students in previous classes have discussed the futility of looking up instructional materials on the Internet and have found existing resources to be confusing for a variety of reasons. By creating these videos, we solve many of the issues that students have encountered. Specifically, information can be tailored to fit the in-class instruction. We can present information in such a way that only assumes knowledge of topics in our knowledge graphs. We can also present solutions that only use content presented in class.

Why the project will be successful

The project is likely to be successful for a number of reasons. The computer science department already has the infrastructure in place to support this approach in CSCI2270 and in our other lower-division classes. This infrastructure includes the automated framework needed to provide students with skills assessments for each concept, knowledgeable faculty on video best practices, and a centralized repository where those videos can be stored and easily accessed by students. In addition to the infrastructure, we also have faculty support amongst the instructors teaching the lower-division classes that this approach will benefit students. For example, in our newly created CSCI1200 – The Art of Computational Thinking course, created this year for non-computer science majors, we are already incorporating mastery based learning concepts using online videos.

The computer science department is already using our computing infrastructure to implement concepts from mastery based learning to some degree. Our department auto-grader, known as COG, allows students to submit their work an unlimited number of times until the assignment deadline. Students can correct their mistakes and resubmit their work. COG is used in all of our lower-division classes and a few of our upper-division classes. We also use a coding framework for smaller programming questions called CodeRunner, where students can submit their code, receive feedback, and resubmit to correct their mistakes and improve their grade. All of our lower-division classes and many of our upper-division classes use CodeRunner and allow multiple submissions of assignments. In previous semesters of CSCI2270, some students have requested more CodeRunner questions to provide them with more opportunity to practice key concepts, indicating that additional materials will be useful for motivated students who need a little extra help.

Broader Impacts

This project has the potential to impact all of our lower-division classes, as well as some of the upper-division classes. The computer science department is facing an enrollment explosion, and we are constantly researching ways to scale our classes that still provides individual students with the support they need. As a group, the instructors who teach lower-division classes have frequent conversations about how to teach given topics and the usefulness of particular resources. If this project is successful in CSCI2270, a similar approach can be applied to CSCI1300. Our CSCI2824 – Discrete Structures instructor has also expressed interest in applying this approach to his classes as well. As previously mentioned, our CSCI1200 already implements many of the facets of mastery based learning, and our computing infrastructure supports assessments that allows students to work at their own pace and submit work multiple times to get the correct answer. Incorporating more mastery based learning into our classes would not be a major change in many cases, but rather, a deepening of some of the work we're already doing.

Assessment

We can gather data on how frequently students use the videos we create, how effective the videos are at teaching fundamental concepts, and how this new approach contributes to student understanding of the material overall. Our videos will be available on YouTube, which provides analytics on how many people watch individual videos, and when they are watched, e.g. right after lecture or right before a quiz is due. We can also survey students about how valuable they perceive the videos and exercises to be for understanding the material.

We can support evidence-based teaching practices by comparing student performance in the Spring 2018 course to student performance in the Spring 2017 course taught by the same faculty member. We store student evaluation data for every semester and could easily compare student grades on midterms and assignments between semesters. We can also evaluate student understanding of individual concepts using our knowledge graphs and a concept inventory of the expected understanding at the end of the semester. We did not have this option in previous semesters.

Budget

The funding for this project will be used primarily to hire an hourly, undergraduate student to develop the knowledge graphs for each lecture and assignment, as well as the instructional materials and assessments. The student has already been identified, and in fact, is already working on the project.

Item	Amount
Academic license for Camtassia recording software	$180
Salary for hourly student	$820

6. Resources leveraged. Grants that propose leveraging existing internal or external resources are preferred – such as financial resources, awards, or collaborations with other units or programs.

There are two phases to this project. This proposal is to support the first phase, which is the creation of the knowledge graphs and materials. The $820 should be sufficient for the student to make progress on this phase, and possibly complete it.

If there are materials that the student doesn’t create in the first phase, the work will be completed in the second phase. In the second phase, the same student will work with the course instructor (Rhonda Hoenigman) to implement this approach in CSCI2270 in Spring 2018. The student will be employed as a Course Assistant by the computer science department CS to oversee the project, including managing the online resources, monitoring how students are using the resources, creating new resources as needed, and collecting data.

References

1. Falmagne, Jean-Claude, et al. "The assessment of knowledge, in theory and in practice." *Formal concept analysis*. Springer, Berlin, Heidelberg, 2006. 61-79.

Agreement to expectations

I agree to fulfill the "expectations of successful applicants," as described below in the request for proposals.