Redesigning a Computer Science Capstone Course with Micro-credentials

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***Abstract*—This Innovate Practice work-in-progress paper investigates micro-credentials as an approach to redesign a course taught by several different instructors in our department. The course involved in this research is a 100-level Computer Science capstone course in Python programming language. This course is mainly designed for freshmen in Computer Science major, but is also available to all the students in other majors. Because of the increasing number of students who are interested in learning programming, the department has to provide at least half a dozen of sessions each semester. Those sessions are usually taught by several faculty members, and in our case, the department has no guidelines on the course design other than a set of student learning outcomes. The instructors of each session can make course design decisions by themselves, including the textbook to use, the material to cover, etc. In this project, we present a course design methodology based on a common set of micro-credentials for this course. Micro-credentials are a set of academic competencies which the instructors expect the students to develop in the course. This paper presents one instructor's course evaluation and redesigning process, showing micro-credentials can help instructors identify the topics which are not covered sufficiently. The process presented in this project could also be used to align the course designs of different instructors on the same course.**

Keywords—micro-credentials, badging, capstone course design, computer science education

I. INTRODUCTION

Since many engineering majors require students to take entry-level computer science courses, it is common for a computer science department to offer half dozen or even more sessions of the same entry-level course in one semester (usually introductory programming courses with Python or Java). Those sessions are usually taught by several different faculty members.

With multiple instructors teaching different sessions of the same course, it can be challenging for a department to make sure that all the designed topics and concepts are covered. As a result, it is possible for an instructor of a higher level course to find his/her students did not learn certain concepts from the prerequisites capstone course(s). In the extreme case, different faculty members may use different textbooks and design their lecture notes based on their preference. If so, other than a set of course learning outcomes, the department has little control over the course designs from different instructors.

One of the approaches to guarantee all the student will learn the same set of concepts/topics is that the department designates a course coordinator who will be the main designer of the course. The coordinator is usually in charge of selecting the textbook, preparing the lecture notes and making sure that all the instructors follow the course design closely. Even having a course coordinator can encourage all the instructors to use (almost) the same course design, it still cannot guarantee the coverage of the topics in the tests and assignments (usually instructors still have control to their homework and quiz questions).

In this paper, we present a new course design methodology based on micro-credentials to 1) make sure that the instructors of the same course have the same coverage of important concepts/topics, 2) give the instructors flexibility in course designing, and 3) ensure that all the concepts/topics are covered in the exercises and quizzes. The micro-credentials are a set of fine-grained credentials/skills which instructors expect students to develop from their courses [1]. Former research related to micro-credentials focused more on the impacts on students, e.g., the impact on students' motivation [2], but did not pay enough attention to the impact on course designs.

In this project, we argue that micro-credentials can not only be used to assess students' competencies/masteries, but also be used to help different instructors to create their own designs of the same course. It is even more important to instructors of a low-level capstone course which has many sessions open each semester. We carried out a pilot study to develop micro-credentials and apply them as a course design mechanism from one instructor who taught sessions of the same course (CSC 131: Introduction to Computer Science) in two consecutive semesters. The processes of evaluating and redesigning the course material are reported.

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II. Research Background

A. Course Involved

The course involved in this research is CSC 131: Introduction to Computer Science in University of North Carolina Wilmington. The goal of this course is to introduce "problem solving methods and algorithms in a modern high-level programming language" [3]. Python has been used as the main programming language of this course since 2009. All the students in computer science major are required to take this course as a capstone course. However, roughly 50% of the students in this course are non-Computer Science majors.

The teaching staff is using the same student learning outcomes, which is the only common part of the different course designs by different instructors. Figure 1 shows the first four items of the student learning outcomes out of 8.

1. Students demonstrate an understanding of basic programming concepts including data types, variables, modularity, parameters, conditional statements, iteration, and arrays.
2. Students demonstrate program development techniques to describe and understand the problem statement, think through input/process/output, leading to problem representation and finally coding.
3. Students demonstrate the ability to use program control structures (i.e., iteration, conditionals).
4. Students develop and use algorithms to solve a variety of problems, for instance those related to array processing, statistical calculations, image and audio processing, and text processing.

Fig. 1. Part of the student learning outcomes

As shown in Figure 1, the student learning outcomes are general and to a certain extent, vague. They describe what general concepts should be covered (e.g., conditional statements), but not necessarily the depth of each concept to be covered (e.g., if-else statement, chained conditions structure, and nested conditions structure, etc.). As a result, it is possible that teaching staff may cover concepts in different depth and thereby, having some students not well-prepared for the next capstone course.

B. Different Course Designs/Teaching Strategies

Since the instructors are free to design their own courses, we have found a big variety of different designs from the teaching staff who have taught this course. Among the instructors who have taught this course in past two years, 4 different textbooks are used, two instructors do not use course slides (instead, they mainly use a whiteboard to present the course material) , three instructors use course slides.

The course projects are also designed differently. The instructors tend to design their course to include the topics which are related to their research interests. For example, one instructor is interested in video games and graphics, therefore that instructor uses graphics to present concepts whenever possible (for example, with Python Turtle Graphics). Another instructor who is interested in data science and machine learning designed a course project which asks students to explore a movie rating dataset. The instructors are mostly enjoying their freedom to design their classes (based on discussion in department meetings), and incorporating problem-solving related their research can potentially help them find students who are interested in working with them in future research projects.

III. Course Design with Micro-credentials

To better evaluate the coverage of topics from sessions taught by different teaching staff, and still allow instructors the freedom to design the course in their own style, we propose a new course design methodology based on micro-credentials. This section presents the development process of micro-credentials and how those micro-credentials impact the course design/redesign process.

A. Development of Micro-credentials

First, each micro-credential is associated with verifiable data and evidence [4]. A micro-credential should represent a skill that the students are expected to develop in the course, and the teaching staff should be able to use one question, or even part of one questions to test whether a student has achieved it.

Second, we kept the smaller grain size for each micro-credential. The grain size of the micro-credentials is one of the existing questions for the research community. Some existing sets of micro-credentials have coarse grain size, for example, NC State has developed a set of 15 micro-credentials for daily skills that teachers need in their classrooms [5]. For our case, however, we tried to create micro credentials of finer grains size to identify the fine-grain topics to be covered. Figure 2 shows our micro-credentials related to the conditional structures.

- Creating code with one pair of if/else branches
- Creating nested if/else branches
- Creating chained if/else branches
- Writing loops with if/else statements

Fig. 2. Part of the course micro-credentials

These micro-credentials cover the different variations of the if-else conditional structures that students are expected to understand in the course. The teaching staff can easily create short exercise/assignment questions to test students' understanding of those micro-credentials.

B. Redesigning a Course with Micro-credentials

We created a total of 113 micro-credentials based on the course involved in this research. The sequence of the micro-credentials is based on when the topics are *fully* presented in the lectures (it is possible that one concept was used in one lecture, then fully explained a later lecture). Then we tagged all the lecture notes and exercise with the micro-credentials

covered. A data analysis was carried out to identify the micro-credentials that students are not practiced enough, or completely not covered by any exercise questions (data analysis results are presented in section IV).

After the data analysis, we changed the course design strategy from "covering the content from the student learning outcome" to "covering the micro-credentials we planned to cover". We changed the designs on both lecture notes and exercise questions. The changes were mostly focused on covering and revisiting the micro-credentials which were not covered sufficiently by the former course design.

IV. Experimental Results

We used the course materials created by the same instructor in the CSC 131: Introduction to Computer Science course in fall 2017 and spring 2018. Each lecture was divided into a lecture section (around 60 minutes) and a lab section (around 40 minutes). In the lab sections, students typically work on programming exercise questions related to the new topics they learn.

Fall 2017 was the first semester that the instructor taught this course, and the course materials (lecture notes, exercises questions, etc.) were created based on the course textbook [6]. The set of micro-credentials was created before the spring 2018 semester. After creating the micro-credentials, a redesign of the course materials was carried out. In both semesters, there were 23 classes (excluding the review sessions and in-class exams), and there were on average 4.6 exercise questions for each lecture.

We have manually tagged all the lecture notes and exercise questions based on the micro-credentials. The tagging was done in a "binary" way: one lecture note/exercise question is either tagged as a 1 (presenting/testing one micro-credential) or 0 (not presenting/testing one micro-credential).

Figure 3 shows the coverage of the micro-credentials by the lectures in fall 2017. Each row in Figure 3 represents one micro-credential and each column represents one lecture. The bright color means that a micro credential is covered in a specific lecture. From Figure 3 we found that most of the bright blocks are in the diagonal, which was as expected because the sequence of the micro-credentials was based on the sequence of when they are fully presented in lectures. The bright blocks on the upper-right side mean that in some of the lectures, the instructor refers back to micro-credentials students have learned earlier. Those are mostly necessary reviews of former concepts related to the new topics presented.

Figure 4 shows the coverage of the micro-credentials by the exercise questions in fall 2017. Each row in Figure 4 represents one micro-credential and each column represents exercise question. The bright color means an exercise question is designed to test students' understanding of one micro-credential. From Figure 4 we found that most of the bright blocks are in the diagonal, which was as expected because most of the exercise questions were created to test the concepts students learned in the lecture on the same days. There are more bright blocks in the upper-right area because the instructor tried to combine the concepts learned before to the new concepts when creating exercise questions.

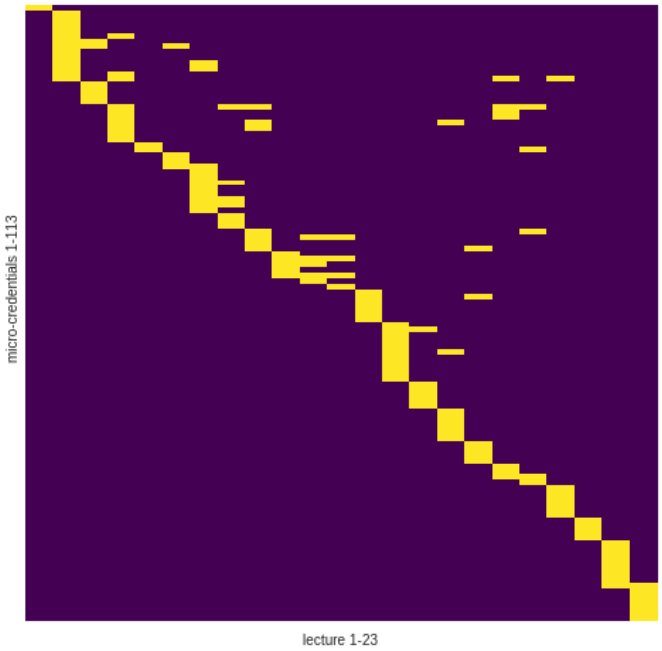

Fig. 3. Heatmap of the micro-credential coverage by lecture notes

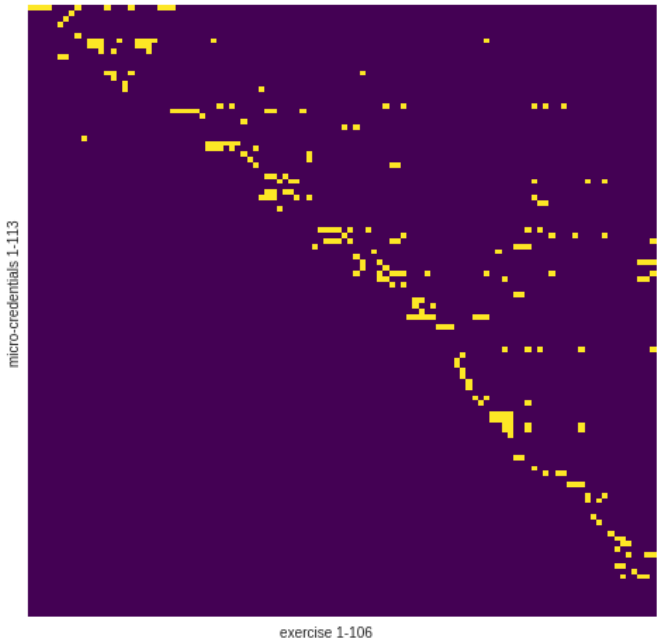

Fig. 4. Heatmap of the micro-credential coverage by exercise questions

A. Finding Untested Micro-credentials

Though some micro-credentials are more important than others and thereby deserve more exercises, the teaching staff should try to minimize the number of insufficiently covered micro-credentials. To find the micro-credentials which the exercise question did not cover enough, or did not cover at all, we compare the aggregated coverage of the micro credentials

in lectures and exercises in fall 2017, as shown in Figure 5. Each row in Figure 5 represents one micro-credential and the two columns represent all the exercises (left) and all the lecture notes (right). The brighter color means that a micro-credential is covered more by the lecture notes or exercise questions. The columns were scaled to the range.

From Figure 5 we found that though the lecture notes covered the micro-credentials well, there is a big portion of dark blocks on the left column, showing some micro-credentials were not practiced enough by students, or even not practiced. Especially, the large dark block on the bottom-left shows that the students did not have any exercises to practice the micro-credentials they learned in last a few lectures. Further data analysis found that a total of 35 micro-credentials were not covered in any exercise questions in Fall 2017.

From the list of insufficiently practiced micro-credentials, we found that some of them can be easily covered by exercise questions. For example, one of the untested micro-credential was "Adding documentation strings to a function". The instructor added one exercise to test this micro-credential during the course redesign before spring 2018. However, there were some other micro-credentials which are more theoretical, thereby, are harder to be tested by the exercise questions, e.g. "Understanding the accessibility rules of variables in a program with functions". In this case, the instructor designed more examples/pop-up quizzes in the lectures to help students fully understand the concepts.

B. Improving the Coverage of Micro-credentials

At the end of spring 2018, we tagged the course materials again with the same set of micro-credentials. We found that the micro-credentials coverage by the lecture notes was almost the same as presented in Figure 3. However, after redesigning the exercise questions, they were able to cover more micro-credentials. Figure 6 shows a comparison between the coverage of micro-credentials by exercises in fall 2017 and spring 2018.

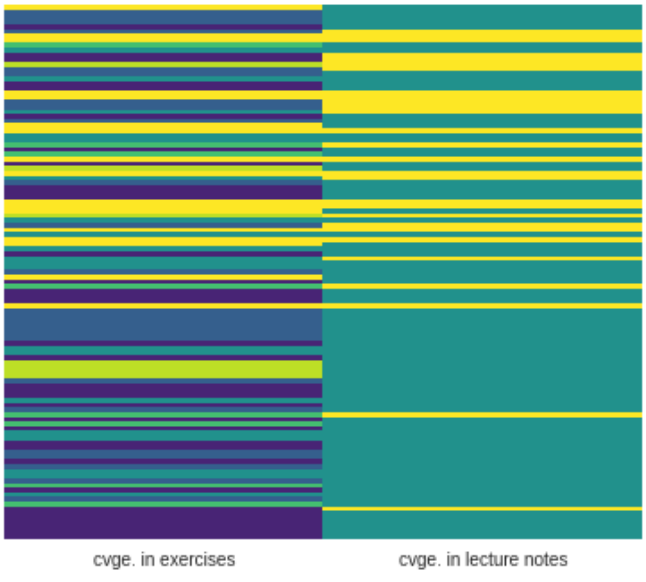

Fig. 5. Comparison of the micro-credential coverage by lecture notes and exercise questions

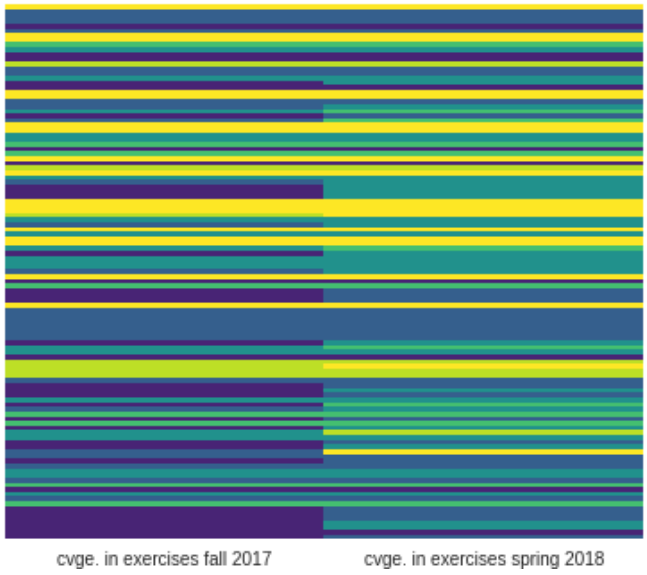

Fig. 6. Comparison of the micro-credential coverage by exercise questions in fall 2017 and spring 2018

From Figure 6, we found that after the redesign of the exercise questions, there are less dark strips on the right column (spring 2018) than on the left column (fall 2017), showing that the exercises covered more micro-credentials in spring 2018. The remaining dark strips in the right column are mostly the theatrical micro-credentials which are harder to be tested by programming questions. However, the instructor managed to cover them with pop-up quizzes.

V. Conclusions and Future Work

Micro-credentials are originally proposed to recognize students' skill acquisition. Researchers have found micro-credentials to be helpful as a motivational tool, or an achievement recognition mechanism [7]. In our project, we found that micro-credentials can also be a helpful tool in designing and redesigning a course, especially in identifying the topics that students are not presented or practiced enough. The instructors, later, can redesign exercise questions or add pop-up quizzes in classes accordingly.

In the next semester, we will involve more instructors in this research and use micro-credentials to "align" the course designs by different instructors of the same capstone course.

We are also planning to build an online question bank which supports the association of micro-credentials to exercise questions. This system allows students to take exercise online and records students' behavior, including the number of trials on each question. Base on students' records, we can create a course competency portfolio for each student before they take the next capstone course.

Acknowledgment

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