Teaching Cybersecurity Masters: Student Coding Assessment and Engagement with Online Content

Siva Raj Rajagopalan, Tatiana E. Tchoubar, Yi Lu

New York University, Tandon School of Engineering
NY, US

Abstract

Cybersecurity workforce is experiencing rapid growth due to the scale of cyberattacks. NYU Tandon Online created an innovative Masters Cyber Fellows program for the working professionals willing to level up their skills in response to the job market demand. Teaching online one of the foundational courses of the program, Information Systems Security Engineering and Management, necessitates catering to a heterogeneous student population, including recent Bachelors in Computer Science as well as many years' graduates from other fields who change their professional path as a part of life-long learning. Course requires programming in Python, so getting all the students to acceptable proficiency in coding represents a challenge for the instructor, teaching assistants and the instructional designer of the online course. Another imperative need is to scale up the coding assignment assessment and grading, because of the high enrollment numbers. Using an experimental approach, course teaching team implemented group assessment. The innovation in group formation was based on inclusive course design, where each group had a role of "coder" filled following the outcomes of a Python pre-test administered to all the course students at the start of the course. Such equitable group formation improved student success with coding assignments and with final project, as well as relieved the pressure on teaching assistants allowing them to increase the quality of one-on-one consultations. Engagement of the students with the online course content was stimulated by including the links to the weekly readings directly in the Quiz question hints. These two instructional design innovations significantly improved student success and satisfaction with online cybersecurity teaching and learning. Recommendations are provided for the future research.

Keywords: *student assessment, E-learning, adult education, enhancing student engagement, online content, backwards learning*

1. Introduction and litterature review

1.1 Cybersecurity courses

Cybersecurity teaching is of unquestionable importance to society. One of the primary challenges in effective training is the stereotypes that are associated with cybersecurity, much more so than with any other field of technology. The second main distinctive feature of cybersecurity teaching as revealed by the fieldwork in [1] is that cybersecurity is still a practice-oriented area of study that is learned by an apprentice model.

Earlier publications on cybersecurity education reported on situation awareness-oriented cybersecurity education [2], peer learning activities in cybersecurity [3], and analyzed the cybersecurity master programs in the context of the discipline evolution [4]. Research-based learning [5] and using multimedia explanations [6] have been demonstrated to benefit digital teams. This study applies the project group learning and online content to facilitate cybersecurity teaching.

1.2 Backwards design and backwards learning

Backwards instructional design has been introduced in higher education since the 1990 publishing of the book "Understanding by Design" by Grant Wiggins and Jay McTighe [7]. Recent research has suggested the evidence that not only the instructors could use the backwards design, but the students are, on their own, proceeding "backwards" in their appropriation of the online weekly content: they look at the assignments first, and deduce what lectures and readings do they need to complete the assignments [8]. In our paper, we verified this suggestion through a rigorous experimental design.

2. Benchmarking

The course under discussion is an online-only one-semester course on practical cybersecurity for systems architects that is targeted towards enabling graduates to join the workforce as security architects without any significant on-the-job training. The Cyber Fellows program in which this course is offered is targeted towards a heterogeneous audience in the middle of their careers. Students have varied backgrounds and employment experiences ranging from law school, policy think tanks, social work to technical management. Many of the students were new to Computer Science before they entered this program. Making cybersecurity accessible to such a diverse audience is particularly challenging, especially in the online setting, due to the strong possibility of online isolation among students. To address this we have used group-based homeworks to facilitate peer learning. Finally, in light of the learnings from [1] we have constructed a hybrid course that combines theoretical concept learning with practical software writing exercises that not only reinforce the conceptual learning, but also better prepare the students for the nature of the job in the real world.

3. Research Methodology

3.1 Goal and Research Questions Observational case study described here was conducted in the context of a course on cybersecurity that is now being taught in its second offering. We did not change the teaching methodology in any way based on our observations in this semester. The **goal** of this course was to make the students "job ready" using novel teaching methodologies. For example, an important training for the job market is the ability to work in a team to prepare quality deliverables. We also measured the effectiveness of our teaching approach. We were investigating two **research questions**: (1) How did the Python pre-test impact group performance (qualitative) (2) Do the students use a backwards learning approach to online content?

3.2 Sample The sample counted 59 cybersecurity masters' students with diverse backgrounds, in mid-career average age, spread across five time zones.

3.3 Procedure Spring 2022 course cohort have been divided into the coding laboratory groups of four students each, based on a non-graded Python pretest that was given to every student individually with the aims of (i) assessing their python coding ability and (ii) giving pointers to python tutorials to those whose coding abilities were weak. Each group was assigned a "coder" who was one among the 15 highest scorers in the pretest, along with three other members chosen at random. This group was required to do all 9 coding labs, one written theory homework, and the final project together for the entire semester.

Every week the students were assigned a required reading, typically a presentation or research paper on the topic of the week. Short individual quiz tested the students on the material of that week. The students were divided into two equal groups A and B at random, with weekly rotation. Both groups were given the same quiz but Group B received a hint for the questions related to the reading assignment whereas Group A did not get any hints. All quizzes allowed for at least two attempts, our research observations were able to differentiate the students' performance at each attempt.

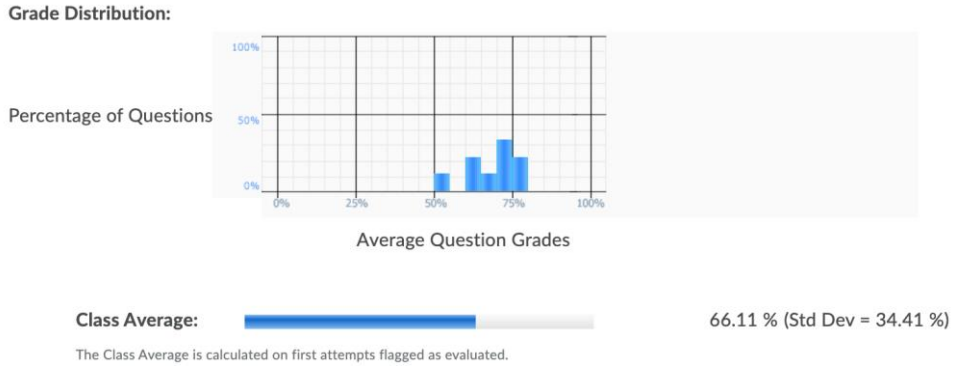
3.4 Data Collection and Analysis

Course usage data from NYU LMS provided grades, time spent on the course site/learning module, number of hits on the course content, and the frequency of participating in the learning activities. Professor has conducted course evaluations to collect students' feedback on the course content and meaningful interaction. By running the data analysis, we were able to pinpoint the factors that promote student learning outcomes. We plan to reinforce those factors in the program update.

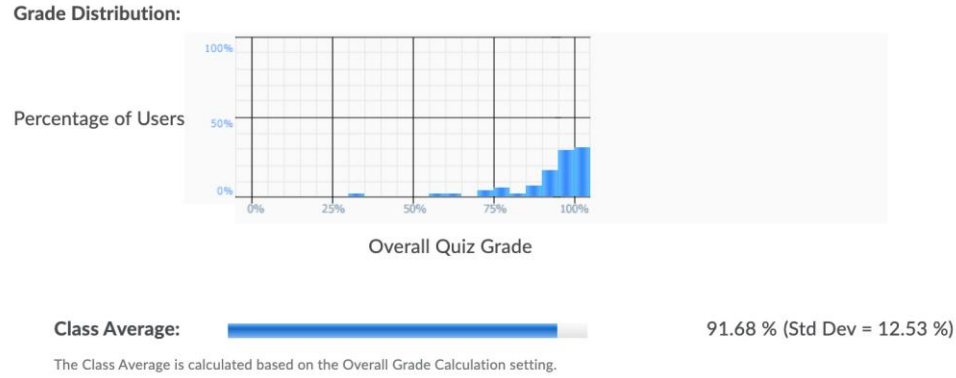
4 Results

4.3 Pre-test in Python and **Group lab assignments**

Assigned one month prior to the course start, the pre-test consisted of 9 questions on Python language programming, each question providing a hint with the link to the Python tutorial. The first attempt class average was 66%, with some answers being correct only half of the time.



Between the first attempt and the second attempt, the students had an opportunity to take recommended Python tutorial that significantly improved their grades. The overall class grade average resulted in 91%.



4.4 Mid-semester and end of semester student surveys

Student survey revealed positive feedback on group assignments (88%): “Working in a group was nice…Great collaborative experience… The course added to my knowledge of cybersecurity a lot. I also managed to make new professional connections with other students through discussion groups and lab groups.” More than 60% of the students found that the Python pre-test helped them with completing the labs.

4.3 Engagement with content and quizzes

The success of the pre-test link to tutorial gave us the idea of adding the links to the content readings into the hints for each quiz question.

Quizzes A and B have recurrent differences in average grade for the questions #3 and #4 that offered a hint for group B only (Fig. 1), even though the new groups were formed randomly every week, so that to avoid discriminating any student.

Quiz Name / QuestionNumber	z B % rect	W8 Quiz B % Correct	W8 Quiz A % Correct	W9 Quiz A % Correct	W9 Quiz B % Correct	W10 Quiz B % Correct	W10 Quiz A % Correct	W11 Quiz A % Correct	W12 Quiz A % Correct	W12 Quiz B % Correct	W13 Quiz A % Correct	W13 Quiz B % Correct	W11 Quiz B % Correct
1	5%	96%	100%	63%	64%	88%	82%	95%	89%	83%	97%	92%	99%
2	3%	100%	100%	100%	100%	88%	71%	95%	78%	79%	96%	93%	99%
3	4%	86%	73%	93%	96%	86%	100%	97%	96%	80%	93%	95%	99%
4	4%	100%	100%	100%	100%	88%	96%	95%	59%	78%	88%	89%	99%
5	4%												
6													

Easier Questions

Difficult Questions

Figure 1. Average quiz scores, by question (four questions in each quiz)

One way to confirm the effectiveness of the Hints in Quizzes for Weekly readings was to count the percentage of the students in each of the groups A and B who actually have read the weekly reading. We observed that the students in Group B, who received the hints with links to readings, consistently have spent more time on reading than the students in Group A, who didn’t have any hint in the quiz, but still had access to the same required weekly reading (Fig. 2).

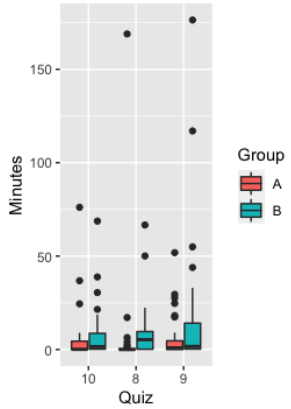


Figure 2. Time spent on content every week by the students in Group A (without hint, in red) and Group B (with hint, in green).

5 Discussion

A unique aspect of this course was that it was designed and taught by an instructor who is not only experienced in performing the security architect job in the industry but also in a position of hiring the security architects that were being prepared in the course. He designed the course to mimic real world work dynamics such as working in groups on the labs, mandatory topic-based discussion group participation, and peer group feedback. The results of our research are encouraging in that they indicate that there is a positive correlation between our choice of group assignment and the performance of the groups in the lab assignments over the course of the semester. Furthermore, as the data above shows, the availability of hints has a positive effect on the students in encouraging them to access the assigned reading which they would not do otherwise.

6 Conclusions. Future research recommendations

Our extensive experience with online teaching has shown that forcing students to work in groups where they have to collaborate with other students who are strangers has a beneficial effect in creating a conducive dynamic for peer collaboration, which is often missing in the online student's experience. What our current work has revealed is that it is important to pay attention to the skills component in group formation. In this experiment, we have only used the coding skill as the controlling variable for group selection. In future, other factors such as interests or background diversity can be considered. SImilarly, our experiment hints that backwards learning is a strong determinant of student behavior, which leads to a natural question for future research, namely, how can we use this known student behavior to create better outcomes for students in an integrated learning environment.

7 Acknowledgements

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