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Designing a Visual Analytics System to Support a Re-designed Flipped Learning Programming Class

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Abstract

Enhancing students' programming skills has become a critical issue. The development of video streaming technology makes MOOCs an innovative and convenient way to learn programming. However, programming novices were still plagued by the high failure rate of conventional teaching methods. Therefore, this study aims to design a visual analytics system based on the re-designed flipped learning programming class. The re-designed flipped learning model contains a collaborative and co-regulation process. This study designed the instruction activity with SPOCs video. Moreover, to promote students' self-regulation, we create a visual analytics system to collect students' coding logs, video-clicking data, and results of peer assessments. The system contains the coding log dashboard, video clicking dashboard and peer assessment dashboard respectively, so students can easily evaluate their learning process. Moreover, this study conducts the experiment to check whether the proposed system and the new class module enhance students' learning achievement and motivation.

Keywords: Flipped Learning, Learning analytics dashboard, Programming education, Self-Regulated Learning

1 Introduction

Computer Science education has been getting more attention in recent years. As a result, cultivating students' programming skills becomes an important issue. In the meantime, the development of network technology and video streaming technology has made MOOCs an innovational and convenient way to learn programming. However, programming novices face difficulties in conventional methods with high failure rates [1][2][3]. Therefore, higher education institutes started to adopt SPOCs (Small Scale Private Online Courses), a classroom model using MOOCs as supplementary material in face-to-face courses with limited student numbers [2][4]. With limited student numbers, teachers can adaptively design the materials for each student, which is why researchers believe SPOCs will be successful [5]. On the other hand, there are relatively few tools for the teacher to analyze the problems students encounter while watching videos. Besides, online courses possess a high degree of autonomy, which makes it necessary for students to adopt self-regulated learning [1][2][3]. But there is still a lack of tools for students to keep track of their own coding performance and video-learning process while adopting SPOCs in a programming class, so they are hard to do reflection in a self-regulated learning process. Therefore, we design a visual analytics system to support students in evaluating their coding and video learning process.

Moreover, problem-based learning can enhance students' learning effectiveness [6][7]. This paper combines problem-based learning with a re-designed flipped learning model [8], which

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contains co-creation and co-regulation processes to deal with the high failure rate in the traditional teaching way [9]. Furthermore, we combine SPOCs as a scaffolding of these models and collect students' clicking data while watching course videos and their coding action history to create dashboards. By watching dashboards, the teacher can keep track of students' coding performance and find out which students are facing problems while watching videos, students can check out their performance weekly to improve their coding and clicking actions through Self-Regulated Learning. This paper aims to check whether a programming class combined with problem-based learning and a re-designed flipped learning model supported by SPOCs is helpful for students' programming skills and learning motivation. The research questions of this paper are listed as follows:

1. Can our proposed system improve students' learning achievement?
2. Can our proposed system improve students' learning motivation?

2 Literature Review

2.1 Programming education in the Flipped classroom

Due to the high failure rate of classes for programming novices, many studies have been proposed to enhance those novices' learning achievement [10]. Such as using problem-based learning to enhance students' learning effectiveness [6][7] or observing students' programming processes [11][12]. Researchers also mentioned that as students' programming process became valuable, students' programming action log availability improved [12]. In addition, students' programming behavior also becomes an indicator of students' learning performance. Therefore, researches such as investigating students' errors that occurred during programming [13] and predicting students' learning performance by their programming log [14][15] have both become innovative research in the field of programming education.

A flipped classroom (FC) is a model that moves the instruction activity out of the classroom and exchanges it into videos or other types [16]. Students can discuss with the instructor the adaptive guidance during class time [8][16]. In FC, students must be responsible for their learning process and handle their learning progress [17]. Therefore, the challenge of the FC will be the lack of Self-Regulated Learning (SRL) skills [18]. Because the FC will exchange instruction activity into videos, we choose to use SPOCs as part of our instruction activity. SPOCs are a class model proposed in 2013 [19]. It's a teaching mode in which MOOCs videos are used as supplementary materials in face-to-face courses [20], and it limits the number of students and requires some form of formal enrollment [21]. Because of SPOCs restrict the system to specific audiences, it meets the condition for adaptive learning [22]. Therefore, in this research, SPOCs are part of instruction activity and scaffolding problem-solving tasks.

2.2 Regulation and Learning analytics dashboard

The effective collaborative learning requires regulation of the group learning process, making shared regulation necessary, shared regulation refers to the process where team members collaborate to plan, establish tasks, and reflect during collaborative learning process [23]. Hadwin, et al. [24] also mentioned that co-regulation could mediate or transition productive self-regulation, co-regulation means a group member provides guidance and support to others in their SRL processes [25]. We choose to use the re-designed flipped learning model [8], which contains different activity from traditional flipped learning model such as active learning, knowledge construction, co-regulation, collaborative learning, peer assessment & discussion, shared-regulation, student generated content, and embedded assessment to promote students' self-regulated actions. Moreover, SPOCs is suitable for higher education courses based on adaptive learning [26]. We collected students' coding and video-clicking data and created dashboards adaptively. So that instructor can handle every student's learning situation and give them further advice and support.

In recent research, tracking data automatically saved by learning management system, such as the order of students browsing pages or the action while watching videos, was also used to observe students' self-regulated processes [27]. Widespread use of learning management system promotes the capacity to capture students' tracking data about how they interact with tech tools [28]. Increasing of data also promotes the development of learning analytics. Among them, learning analytics dashboard (LAD) has attracted much attention as a component of learning analysis because it can make students understand their learning progress better [29][30]. LAD integrates different indicators about learning through various charts or graphs and helps learners making decisions about their learning [31]. Researchers also indicate the relationship between LAD and students' self-regulating learning strategies [32][33][34], and that LAD can enhance students' understanding of their learning process [29][35].

Due to the limited work to incorporate SRL and LAD into programming courses. In this study, we utilize students' coding log collected by Jupyter hub Server, and video clicking data collected by LMS (Learning Management System) enable students to create self-regulated learning dashboards. Also, we provide the dashboard to teachers and add an interactive function for the instructor to check out the learning performance of single students or the whole class. So that instructors can assist or intervene with students adaptively.

3 Method

Participants in this research were 31 students from a university in northern Taiwan. During this 18-week course, we combined problem-based learning with a re-designed flipped learning model [8]. Besides, we incorporate SPOCs into the class model by giving them video-watching tasks with six problem-solving tasks, videos will be related to the tasks, so they will also be a scaffolding of the problem-solving process. Due to the autonomy of online courses, students must conduct self-regulated learning. Therefore, we utilize the technical tools in the learning management system to support students' self-regulated learning. This study also collects students' coding log files and video-clicking data from each problem-solving task to produce self-regulated learning dashboards, video-clicking data has also been used to find out the different learning patterns between high and low achievement students. At the same time, to conduct the re-designed flipped learning model [8], we designed several class activities to map every phase of the model. Finally, to measure student's learning achievement and the effectiveness of our class design, we conduct pre-test and post-test in the following orientation: learning motivation by the field of Intrinsic Goal Orientation and Extrinsic Goal Orientation in MSLQ [36] and learning achievement by Python skills exam which designed by expert. Mapping between re-designed flipped learning model and class activity.

In contrast to the traditional flipped learning model, the re-designed flipped learning model [8] has several additional components. We tried to map those components to our class activity. The complete flipped learning process and steps are listed as follows:

1. Students receive a task and complete the problem-solving process on Jupyter hub with the support of a class video, besides, take notes on the LMS while watching the video (Active learning).
2. At the start of the next class, the instructor will ask each group to compare group members'

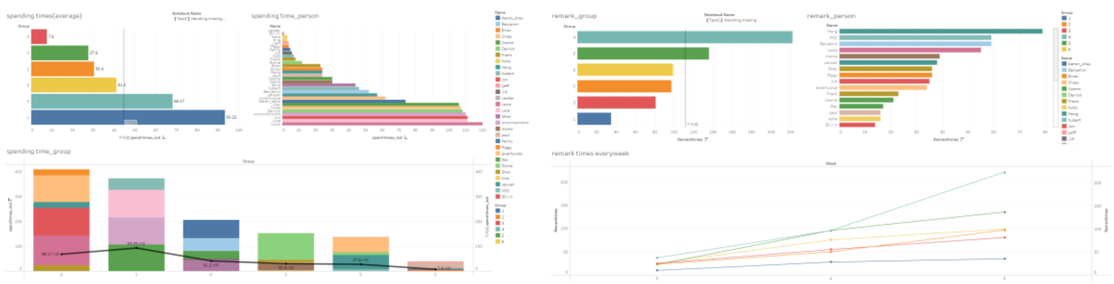
answers and integrate them into one co-creation file. (Knowledge construction, Co-regulation, Collaborative learning)

3. Each group will take turns doing a presentation about their co-creation file. Other groups will grade and advise at the same time. (Peer assessment & discussion)
4. At the end of class, the instructor will provide dashboards about the coding log, video-clicking data, and the result of peer assessment to students. Based on this information, each group can discuss their learning strategy next time. (Peer assessment & discussion, Shared regulation)
5. Each student will fill in an online questionnaire to express their reflection. (Embedded assessment)
6. Each group uploads their co-creation file and notes about the video. Those contents will be free to browse. So students can refer to these contents in future works. (Student generated content)

4 System Structure

In order to make students confirm their coding performance, video-watching action, and the result of peer assessment easily, we construct a systematic data collection mechanism in the system to acquire students' coding logs, video-clicking data, and the peer assessment results. And respectively create three dashboards about coding, video, and peer assessment, so that students can evaluate their performance and develop a new strategy based on the result of the dashboards. Therefore, we built a Jupyter hub server for students to complete problem-solving tasks. At the same time, we collected students' coding logs into MySQL database. In addition, we post the SPOCs videos and the peer assessment form on LMS and ask students to watch the videos and do the peer assessment over there, so we can collect students' clicking actions and the result of assessment by LMS. Last but not least, we do data preprocessing among three data by python and create three dashboards by Tableau.

In the coding log dashboard, students can observe the information about errors such as error rate, number of errors, changes in the number of errors for every task, and composition of different error types. In addition to error data, we also provide time information (see Figure 1(a)) and the number of remarks (see Figure 1(b)) of each group for students to evaluate their performances and think about how to improve their coding action or patterns.



(a) (b)

Figure 1: Coding log dashboard about time information (a) and frequency of remarks(b)

(a) (b)

Figure 2: Video clicking dashboard (a), and Peer assessment dashboard (b)

In the video-clicking dashboard (see Figure 2(a)), we counted the frequency of each clicking action, including play, pause, finish (finish watching a video), rate (adjust playing rate of video), index (check out the topics and content of different time points), forward-seek (from an earlier timestamp jump to a later timestamp) and backward-seek (from a later timestamp jump back to an earlier timestamp) every minute. Besides, we use forward-seek and backward-seek to create seek graph [37]. Due to the horizontal axis of the seek representing the timeline of the video, we can check out the contents of the area with dense line, meaning students repeat the video frequently in that time. So that instructor and students can check out the range of video in that time point and reinforce the concept.

In the peer assessment process, we ask students to rate other groups based on the readability, accuracy, gain, extensibility, and extra contents of their code. Moreover, students will give comments and suggestions to other groups. After peer assessment, we will allocate all those data into a peer assessment dashboard (see Figure 2(b)), so students can evaluate their performance by the comments and develop new learning strategies by the suggestions.

5 Results

In this paper, we use Wilcoxon signed rank test to examine the difference between the pre-test and post-test scores of Python Skill exam. According to the result of Wilcoxon signed rank test (see Table 1), after taking the class and using the system for 18 weeks, students' learning outcome increased significantly (z=-4.316, p=.000<0.001).

Table 1: Wilcoxon signed rank test of Python Skill exam

	Test	M	SD	Z	*p*
Python Skill exam	Pre-test	52.90	11.6027	-4.316***	.000
	Post-test	69.20	14.3234		

**p<.05, **p<.01, ***p<.001*

In addition to learning achievement, we also use Wilcoxon signed rank test to examine the difference between pre-test and the post-test score of students' learning motivation. According to the result of Wilcoxon signed rank test (see Table 2), after taking the class and using the system for 18 weeks, students' overall scores (z=-2.143, p=.032<0.05) of learning motivation test has increased significantly. It means the system and class module are helpful for students to enhance their learning motivation.

Table 2: Wilcoxon signed rank test of Learning Motivation test

Test	M	SD	Z	*p*
Pre-test	3.93	.560	-2.143*	.032
Post-test	4.45	.404		

**p<.05, **p<.01, ***p<.001*

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