A Data-Driven Analysis of Student Efforts and Improvements on a SPOC Experiment

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ABSTRACT

In recent years, Massive Open Online Courses (MOOCs) increasingly attract the attention from all circles. MOOCs provide students with abundant learning resources, which are also utilized by colleges to improve the effect of teaching. Moreover, Small Private Online Course (SPOC) and flipped classroom have been proved to be effective in some STEM courses. In this paper, we conduct a SPOC experiment on *Data Structures and Algorithms*. We leverage both online and offline data to analyze the efforts and improvements of students, including comparing test scores between different classes, collecting student information from questionnaires and exploring the online learning behaviors of students. We also discuss and explain our findings according to the experience which we get from the teaching experience.

KEYWORDS

SPOC, Flipped Classroom, Data Analysis, Computer Education

1 INTRODUCTION

MOOC (Massive Open Online Course) is a kind of both society-oriented and global-oriented course. During recent years, more and more students benefit from abundant online resources, such as filmed lectures, exercises and discussion forums. The rise of MOOCs, with the idea of flipped classroom model, create a new opportunity for education reform [1].

Due to the low retention rate, the purpose of most recent work on MOOCs is to improve the learning effect of online courses. For example, Wilkowski et al. divided students into several classes according to the motivation of the students, and made different criteria for different students [2]. Their work partially explained the low completion rate of MOOCs, and they stated that it would be effective to improve student learning effect by recommending different learning materials for different students. Tomkin et al. investigated the impact of instructional staff on students and found that the instructor interventions have a significant positive effect on overall completion rates, participation rates and attitudes, besides leading to a higher rate of forum badge completion [3].

Since students have different levels of learning skills, it is not reasonable to apply the same videos and syllabus to these students. To address this problem, the idea of SPOC (Small Private Online Course) was proposed by Armando Fox in 2013, which is referred as a version of MOOC and used locally by only on-campus students [4]. Based on the course design of *Software Engineering*, Fox demonstrated that a SPOC, which is combined with online learning resources, can be used as a convenient supplement of traditional learning [5].

The characteristic of SPOCs is that the online learning procedures avoid duplicating class and try to create some more flexible and effective teaching methods. SPOCs can blend the online learning approach with smaller, targeted and revenue generating classes [6]. Deslauriers et al. compared two different instructional approaches and showed that the use of deliberate practice teaching strategies can improve both learning and engagement [7]. Seaton et al. showed that students with different learning skills have different online learning activities [8]. Konstan et al. designed a flipped classroom method for the course and constructed a regression model to predict the completion, knowledge gains and final grades of students [9].

As the students of a SPOC course usually come from the same school or university, the difference of the learners is much smaller than those of MOOC learners. So that the analysis of the course experiment is more reliable. Zhang et al. conducted a "SPOC + Flipped" course experiment on *Data Structures and Algorithms*, and applied statistical analysis to show that students under such teaching mode perform better in algorithm questions of final exams, compared to those in traditional classroom [10]. However, this work simply used a regression to explain the reason why SPOC students perform better. Besides, it only analyzed the offline effort of students, but not the online activities.

Therefore, in this paper, we leverage more data, including test scores, questionnaires and online learning behaviors, to discuss the potential reasons why SPOC classroom students did better in algorithm problems.

* This author is the corresponding author.

ACM TUR-C '17, May 12-14, 2017, Shanghai, China

DOI: http://dx.doi.org/10.1145/3063955.3063956

2 BACKGROUND AND RESEARCH QUESTIONS

In this section, we first introduce the setting of our course experiment, including students, activities and examinations. Then, we briefly compare with a previous work in this area and list three main research questions that we will discuss in this paper.

In 2014 spring, we conducted an experiment on the course of Data Structures and Algorithms in Peking University to evaluate the effectiveness of flipping with SPOCs. Among 828 undergraduate students majoring in science or engineering took this course, 397 of them attended five SPOC classes and the others attended the traditional classes. Specifically, Class A1, A2 and A4 did not strictly require students to finish SPOC tasks, which means the quizzes and programming assignments were used as supplement of learning materials. Class A3 and A5 made full use of SPOC resources and also asked students to preview the online videos before class. The distribution of SPOC classroom students is shown in Table 1.

During the course experiment, students leverage the resources on Coursera, a famous MOOC platform, to watch videos, load lectures, finish online quizzes and programming assignments after each chapter. To observe the learning trajectory of students in SPOC classroom, we collected student online learning behaviours in the form of clickstream. Besides, we also conducted two questionnaires at the beginning and the end of the course respectively.

There are totally four written tests during the course *Data Structures and Algorithms.* Two in-class quizzes were held in the halfway. Besides, we held a unified programming examination at the end of the course, which requires students to write a complete program after given a problem. With the coordination of the office of educational administration in the university, we held a final examination with the same questions at the same time, which is a standardized test of the course. The final examination can be roughly divided into two parts, concept questions and algorithm questions. During our analysis, the scores of concept questions and algorithm questions between different classes are compared after normalization.

The previous work demonstrated that the students of SPOC classrooms perform better than those of traditional classrooms in terms of algorithm questions when learning *Data Structures and Algorithms* [10]. However, that work just simply explained the situation by using a linear regression model to fit the final scores on several variables extracted from questionnaires. Thus, in this paper, we leverage more data analysis to explore the potential reason why SPOC classroom students did better in algorithm problems.

In the following sections, we quantitatively and qualitatively analyze the data of the course and discuss the following issues in details.

1. How do SPOC classroom students perform offline? Specifically, how do their basic background information, offline learning effort and learning experience impact on their performance?

Table 1: The distribution of the students, with Average NCEE scores and the # of students with National Olympic Medals

	Abbr. of classes	# of students in class	# of Student with Gold Oly. Medals	Average NCEE Score[2]
SPOC classroom	A1	74	13	684.33
	A2	90	16	684.33
	A3	95	3	675.67
	A4	77	0	675.83
	A5	61	0	675.83

2. Is "SPOC + Flipped" learning mode helpful for students to improve their programming ability? Since it helps students perform better in algorithm questions, is this kind of teaching mode improve both their algorithm-designing ability and problem-solving ability?
3. Can online learning activities explain the performance of students in SPOC classroom? What is the difference of online activities between students who get higher scores and those who get lower ones?

3 DATASET AND METHODS

The dataset for this paper comes from a SPOC course experiment *Data Structure and Algorithm*, which is held in Peking University in spring, 2014. The data we used for analysis consists of the scores of four tests, two questionnaires and online learning clickstreams. In this paper, we focus on five SPOC classes, where 397 students attend the final examinations in total. Among them, we collect 347 and 292 valid questionnaires at the beginning and the end of the course respectively.

The clickstream of this course is supported by Coursera, which contains around 400,000 records. Each record represents an action of the learning process, most of which are opening a new webpage or playing a video. According to the source and destination of the page-view action, we can infer and classify the type of their online learning behaviors. In this paper, we extract five main kinds of features, which are the common factors impact on students' scores significantly in general online courses.

In assist of these data, we compared the scores of students in different SPOC classes based on their own teaching procedures, and discuss the potential reasons that make them perform better in the finals. Besides, we also use statistical method, such as correlation analysis, regression model, to understand what factors may improve the algorithm performance of students in SPOC classroom.

[2] NCEE denotes to National College Entrance Examination in China, which is a departure from SAT and ACT exams in the United States.

4 ANALYSIS AND RESULTS

In this section, we address three research questions respectively. We first take two questionnaires to discuss the student learning status during the course, including background information, offline effort and learning experience. We then analyze the scores of programming problems in order to find out if SPOC classroom students are prone to achieve the programming ability. At last, we conduct a regression model to detect whether online learning activities play a significant role on their final examination.

4.1 Basic Information and Learning Experience

Two questionnaires were published at the beginning and the end of the course, to investigate student basic information, effort level (most about offline activities), and experience after the end of the course. We collected 347 valid data samples in the first questionnaire and 292 in the second one. The response rates are 87.4% and 73.6% respectively, so that the results are able to represent the average level of the students.

4.1.1 The Basic Information of Students

We first investigate the background of students. 77.1% of the students in the SPOC classroom were freshmen, since this course was delivered to the freshmen in their second term. 30.8% of the students were female. Specifically, the female ratio was relatively high in the school of urban and environmental sciences (class A4 and A5). 69.45% of the students reported that their programming ability was "just so" or "not so good". 67.44% of the students had learnt C language, while the students who had learnt C++ language only occupied a percentage of 24.21%.

Therefore, most students in this course had a basic programming skills, but only a little of them had learnt object-oriented programming language, most students learnt C rather than C++ in the prerequisite course *Introduction to Computing*. In addition, almost nobody had learnt this course before, especially the algorithms.

4.1.2 The Effort Level of Students

Two main kinds of data, reflecting students' offline learning activities, are shown in Fig. 1, which are collected from the questionnaires. One is whether the students learn through other ways, and the other is the learning hours that the students spent every week.

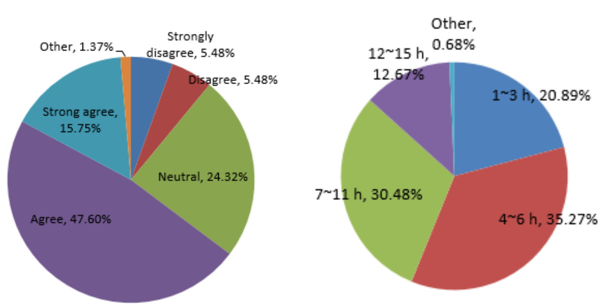

Figure 1: Whether the students learn through other ways and the learning hours that the students spend on learning every week

From Fig. 1, it is obvious that 63.35% of the students learnt through other ways besides learning in the classroom and using SPOC. At the last part of the questionnaire, a subjective question asks students about their gain, and a few students answered that "the ability of self-study was improved". Besides, 65.75% of the students spent 4~11 hours on this course every week, which is relatively normal. On one hand, it indicates that the students worked hard, while on the other hand, it means that only learning through the class and SPOC cannot meet the requirement of the course examination.

Comparing the same question between two questionnaires, 33.69% of the students increase their learning time on this course, 29.39% of the students decrease their learning time, and the remaining 36.92% of the students remain unchanged. Considering all the students in this course, their average time per week spent on learning at the end of this course increased slightly, compared with that at the beginning of this course.

A possible explanation is that although the difficulty of the content increase in the second half of this course and the homework was more complicated, students were more and more familiar with the MOOC platform and formed their own learning method. Moreover, the pressure from the examinations of other major courses may take away the time they spent on this course.

4.1.3 The Learning Experience of Students

To investigate the learning experience of the students, we give some questions and collect their answers. The contents of the questions are:

1. The quantity of this course;
2. The learning efficiency with the resource of SPOC, comparing to the traditional classroom;
3. Time spent on learning in this course, comparing to the traditional classroom;
4. The difficulty of this course;
5. The quantity of homework every week;
6. The exercises are helpful for me to understand the content of this course;
7. Forums are helpful for me to learn this course;
8. This course pays attention to my schedule and reminds me about it;
9. I've got the knowledge and skills which I want to get;
10. Generally speaking, I'm very satisfied with this course.

Because some students only answered several questions before they submitted, the sum of the options (shown in Table 2 and Table 3) may not be 100 percent.

From the result in Table 2, we have the following conclusions. Most of the students consider that this course contains too many contents, as well as the assignments along with every chapter. Students spend more time on learning under the SPOC teaching mode, compared with their expectation. The learning efficiency has been improved, since students can take the use of SPOC resources.

Moreover, from the suggestion to this course by the students, we find that some students got in big troubles because of the difficulty of quizzes and programming labs. They thought that

Table 2: The student feedback of the course settings

Question	Attitude 1	←	Neutral	→	Attitude 2
1.Quantity	More	40.41	56.16	2.40	Less
2.Efficiency	Higher	43.84	43.15	12.33	Lower
3.Time	More	35.62	39.73	23.97	Less
4.Difficulty	Harder	60.96	37.33	1.37	Easier
5.Homework	More	36.30	60.62	2.74	Less

Table 3: The feeling and attitude of students towards the "SPOC + Flipped" teaching mode

Question	Strong Dis-Agree	Dis-Agree	Neu-tral	Agree	Strong Agree	Sum of Agree
6.Homerok	2.05	3.08	12.67	51.03	30.82	81.85
7.Forum	5.48	6.16	40.07	38.70	8.90	47.60
8.Remind	2.74	2.74	19.18	49.32	24.66	73.97
9.Reward	4.79	9.25	29.11	46.58	8.90	55.48
10.General	6.16	10.62	34.25	40.41	7.88	48.29

this course was too hard to follow, and therefore some of them gradually lost their confidence and felt restless.

Table 3 shows the feeling and learning experience of students. The quizzes and rapid feedbacks satisfy the students (only 5% of the student weren't satisfied). And they consider that the quizzes are overwhelmingly helpful for learning knowledge components in this course. However, only 48.00% of the students satisfy with the forum. We think the reason may be that instead of communicating on the forum, students in SPOC classroom can discuss offline on campus, which is more convenient and efficient. The fact that only 48% of the students satisfied with this course mainly due to the difficultly and burden of this course, for there were too many assignments, especially the programming labs.

According to these data analysis, we conclude that students in SPOC classroom take a lot time on completing the assignments, which is beyond their expectation at the start. On one hand, this kind of training make them seize the knowledge components and apply them into a real problem, which deepens the impression of knowledge. On the other hand, the load of this course make students feel depressed and tired. Thus, we think the practice on the MOOC platform is one potential reason that make them outperform students in traditional classroom.

We also interview some students individually and find that they thought their programming skills increased to a relatively higher level after taking the programming practices in this course. Specifically, the programming practices on POJ (PKU Online Judge, http://dsalgo.openjudge.cn/) is helpful for learning programming. They thought POJ let themselves to consider about all the possible situations perfectly and deal with some special cases or boundaries.

4.2 Algorithm-Designing Ability and Problem-Solving Ability

In order to find out the key points that make students in SPOC classroom outperform those in traditional classroom, we research on their programming scores and infer the potential reasons.

We first compare the scores of all four tests between five SPOC classes, and discuss the result based on their different teaching procedures. The comparison is shown in Fig. 2.

The students in A3 and A5 did well in all four tests, especially in programming tests, which thanks for the "SPOC + flipped classroom" learning mode to a great extent. Students in A4 were the best in the final exam, while they were the worst in programming exam. The strict requirements for SPOC tasks and different textbook made students in A4 understand the concepts from different viewpoints, which results in high scores in questions related to concepts, while they did not perform well in algorithms. We think it is because the textbook used by A4 does not require as much as the SPOC in the ability of algorithm. Students in A1 and A2, with higher NCEE score, did not outperform the others, and we conclude it to not strictly requiring students to finish SPOC assignments. Especially, we can see that the flipped class A5 significantly outperforms none-flipped class A1, although the students in A1 got much higher NCEE score and more Olympic Medals in high school.

Moreover, during the course, we not only focus on the concepts teaching, but also take great effort to cultivate students programming ability, including algorithm-designing and problem-solving. We used POJ (http://dsalgo.openjudge.cn/) to publish some programming assignments for each chapter. Through the practice on POJ, students would use the data structures and algorithms properly and then deeply understand the content of the course. In the following analysis, we discuss the comparison of programming test scores, in order to detect whether the "SPOC + Flipped" teaching mode can improve both algorithm-designing ability and problem-solving ability of students.

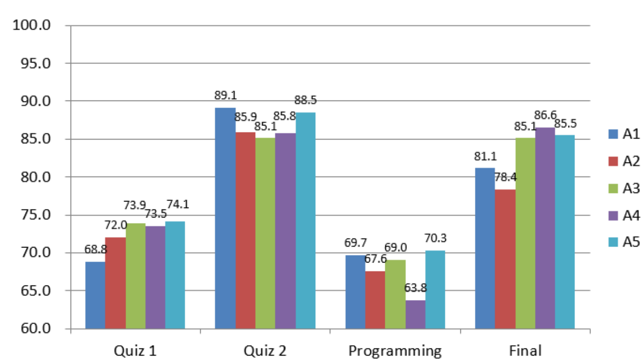

Figure 2: The comparison of four tests between five SPOC classes

Table 4: The correlation between the score of programming examination and both programming and algorithm parts of final examination

Observation N=397	The score of programming exam	Problem-solving part	Algorithm-designing part
The score of programming exam	1	-	-
Problem-solving part	0.4249	1	-
Algorithm-designing part	0.1269	0.2457	1

In this course, two examinations checked the algorithm-designing and problem-solving ability of students. One was the programming exam, and the other was the algorithm part of final exam. The former one checks two abilities simultaneously, for students have to finish a complete program. The latter one checks two abilities by giving students different problems respectively. Thus, we hold a correlation analysis among the score of programming exam, the problem-solving part of final exam and the algorithm-designing part of final exam. The result is shown in Table 4.

According to the result of the analysis, the correlation coefficient of the score of programming exam and problem-solving part in final exam is 0.4249, which shows they have a low positive correlation. In addition, the correlation coefficient of the score of programming exam and algorithm-designing part in final exam is 0.1269, which represents almost no correlation. Thus, students who did not well in programming exam can still solve an algorithm-designing question properly, while the problem-solving questions seem to be harder for them.

We find that students in A4 also performed not so bad in the algorithm questions of the final exam as they performed in the programming exam. It is an interesting phenomena that when checking algorithm-designing and problem-solving ability respectively, they can achieve the requirements of the course.

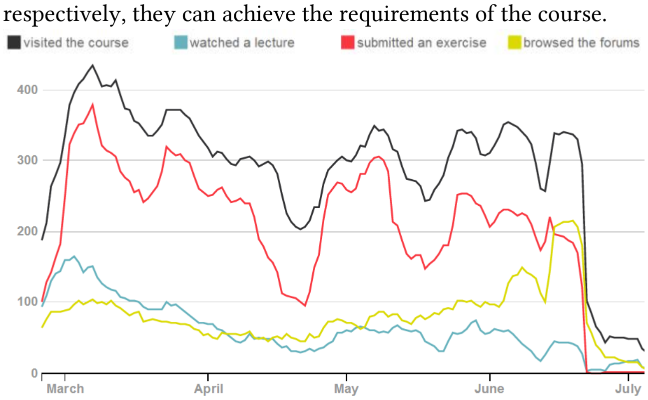

Figure 3: General online learning activities of five SPOC classes

We think one explainable reason is that they achieved the algorithm-designing ability, but did not achieve the problem-solving ability. Besides, students in class A3 and A5 perform well in both programming tests, because the “SPOC + flipped classroom” learning mode make students spend more time on discussing how to solve a problem by using proper algorithms.

Moreover, we think the algorithm-designing and problem-solving ability are interconnected, as their correlation coefficient is 0.2457. As an explanation, when a student is coding, he may receive a “Wrong Answer” from the system, and then check his program and realize his misunderstanding of the algorithm. Conversely, when a student is learning an algorithm, he would be told the situation where the algorithm is satisfied, so that he can choose the appropriate algorithm when he face a real-world problem in the future.

4.3 Online Learning Activities and Learning Effects

We also measure the effort level of the students through their online learning behaviors. Fig. 3 shows the general online learning activities of five SPOC classes, including the student interactions with MOOC websites, video lectures, online exercises and forums.

The grade and learning effect of students are greatly related to one's own efforts. In the traditional classroom, teachers can hardly measure how many efforts students make on studying. On the contrary, student online learning behaviors can be observed under the learning mode of SPOC, for students' learning activities are recorded in the form of log files, called clickstream.

Table 5: OLS Regression for detecting significant factors impacted on students' learning effects

Factors	**Coefficient**	**Standard error**
Viewing pages	0.00467*	0.00222
Watching videos	-0.00103	0.00170
Quizzes	0.0839	0.0519
Programming labs (POJ)	-0.00304	0.0222
Forum Posts	0.0793	0.0724
Intercept	78.258****	1.548
N	346	
F	5.262***	
R-square	0.0718	
Adjust R-square	0.0582	
Note	*p < 0.05; **p < 0.01; ***p < 0.001; ****p < 0.0001	

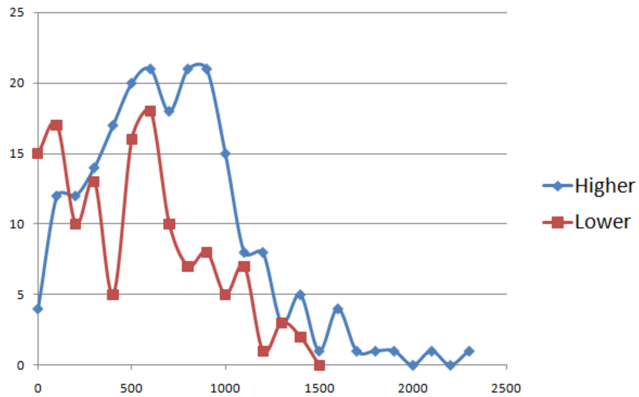

Figure 4: The distributions of times that students who got higher/lower scores visited the course website.

We try to analyze the data of student online learning activities, in order to detect some factors which significantly impact on students' learning effects. Based on that, we compare the students with higher score and those with lower score, and analyze the reasons that cause the difference.

We collect five kinds of features through the clickstream of student online learning activities, which are common factors impacted on students' scores significantly. These features include the page viewing times, the video watching times, the quiz submitting times, the programming lab submitting times and the number of the posts on the forum. We then construct an OLS regression model to detect which of them would be significant factors impact on student learning effects. The result is shown in Table 5. (Some students didn't enroll the online course but attended the tests, so that the observation is 346 in this analysis.)

Although the R-square is low, the results of regression model demonstrate that page viewing times has a significant positive impact on students' final score, which means the higher students' efforts were, the higher their final scores would be. Nonetheless, the impact of other four factors are not significant, which is different from our common intuition. We think that the possible reasons are widely ranged.

Firstly, the students in the same class are also from the same school, so they could discuss in the classroom or dormitory, instead of using the forum. Secondly, this is a required course in their college life, so that every student has to submit the quizzes and the programming labs to get as more points as possible. Thirdly, students prefer to download the videos, instead of watching the videos online, because of the low network bandwidth in China.

To analyze the distinction between students, we divide them into two groups, one of them has higher scores (85 or more), and the other has lower score (less than 85). We compare two distributions of times that they visited the course website, as shown in Fig. 4. We find that the distribution of times that students with higher scores visited the website is almost like a normal distribution, while there is an abnormally high number of students with lower scores who visited the course website less than 400 times. So, maybe the lack of motivation and learning hours is one of the reasons that they got lower scores.

5 CONCLUSION AND FUTURE WORK

This paper researched on a SPOC experiment of *Data Structures and Algorithms* in Peking University. We discussed about the reasons why students performed well in the algorithm question, by analyzing scores of four tests, student information collected from two questionnaires and the clickstream of student online learning behaviors. We conclude our findings as listed below.

1. Compared with traditional classroom, SPOC students take more time on study. They think it an effective way for learning this course, but the online assignments become a heavy load.
2. “SPOC + Flipped” learning mode make students have more time for discussing how to design a proper algorithm to solve a problem, which improves their programming ability.
3. Students who get higher scores in final exam visited the course website more often, while those who get lower scores rarely used the MOOC platform to study.

Our future work is to personalize the learning path of each student. We are going to use the method of data mining to discover their learning pattern and recommend them a more suitable study plan.

6 ACKNOWLEDGEMENTS

This paper is partially supported by the National Natural Science Foundation of China (NSFC Grant Nos. 61472006 and 91646202) as well as the National Basic Research Program (973 Program No. 2014CB340405).

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