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# Research and Practice of Flipped Classroom in Data Structure

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Abstract. In the traditional teaching of data structure course, teachers impart knowledge and students become passive receivers in the class. In this teaching model, students' interest and enthusiasm for learning are not high, and students' practicality and subjectivity are not prominent enough, and thus the teaching effect is usually not so good. Flipping the classroom can effectively change this situation. Under the flipped classroom model, knowledge is imparted before the class and knowledge internalization is completed during the class. This teaching model is learning-centered. Based on this strategy of the flipped classroom model, this paper mainly researches and practice the flipped classroom in the data structure course. First, we design the flipped classroom teaching in data structure course based on the self-made online judge (OJ) and micro lessons on a massive open online course (MOOC) platform. Second, we discuss the arrangement of activities in the class under the flipped classroom model, which is corresponding to Bloom's cognitive learning objectives. Third, we analytically investigate the effectiveness of this approach. The result of the effect analysis shows that this teaching method is better than the traditional ones.

Keywords: data structure, flipped classroom, instructional design, micro lesson, online judge

## 1 Introduction

Data structure is considered an important and required course for computer science and technology majors and students who want to participate in the programming contests [1-2]. Whether they learn it well will have a great impact on the follow-up courses and even the four-year study. It also plays an important role in arousing students' interest in learning major subjects, improving their learning and practical ability, and cultivating their overall quality [3]. The teaching objectives of data structure are as follows:

- knowledge objectives: master basic knowledge of linear structure, tree structure, and graph structure, including the logical structure, storage structure and corresponding algorithm, master common algorithms such as search and sorting, and have some ability of algorithm evaluation;
- capability objectives: be able to select appropriate data structure (logical structure and storage structure) according to practical problems, be able to solve practical problems with data structure and other knowledge, and have certain ability of algorithm design and program debugging for complex engineering problems;
- quality objectives: to develop the scientific attitude and work style of conscientiousness, seeking truth from facts and active exploration, and form good habits of integrating theory with practice, independent learning, team cooperation and exploration and innovation.

In the traditional teaching of data structure course, teachers impart knowledge and students become passive receivers in the class. In this teaching model, students' interest and enthusiasm for learning are not high, and students' practicality and subjectivity are not prominent enough, and thus the teaching effect is usually not so good.

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Data structure is hard to understand, so it needs students to keep practicing for learning it well. In the aspect of theoretical knowledge, it is difficult for students to understand and grasp it because of its abstractness. As for the practice, students find it difficult in learning algorithm design and putting knowledge into practice to solve the problems effectively. In the traditional teaching process, teachers give lectures on theoretical knowledge and algorithm design and implementation, and students passively take in knowledge. Because the students poorly understand the theory and have few chances to put what they learn about algorithm design and implementation into practice in the class, they do not see the value of the knowledge and are not interested in the course. But the flipped classroom model [4-6] can make students actively participate in the interaction, so it can eliminate the problems of the existing teaching method.

When teaching Data structure in recent years, we have been utilizing the mixed use of traditional teaching and inquiry-based teaching model by using the online judge (OJ) system as the platform of teaching and practice and combing the course with the programming contest [7-9]. Based on this, Data structure course have been offered online via OJ and the course on a massive open online course (MOOC) platform recently, and the flipped classroom model has been introduced to promote students' self-exploration, provide more practice, and make the teaching process learning-centered [10-11]. Each short teaching video (micro lesson) online lasts no more than 15 minutes, which allows for personalized and fragmented learning by students themselves. OJ can automatically assess the correctness of the programs submitted by students. It has many advantages, such as providing access to all students anytime and anywhere through the network, evaluating the programs immediately after being submitted, arousing students' interest and inspiring them. It is a platform for students' inquiry-based learning, online practice and testing, and it also can improve students' ability to put what they learn into practice. Data structure related exercises on OJ platform include elementary exercises, exercises in which students need to analyze and solve practical problems with the knowledge mastered, extended exercises and other exercises. Students can learn by themselves according to their learning ability. Exercises for a contest on OJ platform can help students to learn more about programming design and makes them more innovative. A lot of programming practice on OJ platform can improve students' ability in analysis and problem-solving, which help them develop. Based on the brief introduction of the flipped classroom model, this paper also discusses how students preview what they will learn before the class, how they learn the course on MOOC platform, and how to apply such mode in teaching Data structure, to provide the basis and an example for teachers who intend to use this approach.

There are many research results about flipped classroom, such as [4-6, 10-20]. Flipped classroom needs instructional design [15] and peer instruction based on collaborative group [18], and may need time management strategies [13]. Flipped classroom can improve students' satisfaction and learning performance [12]. There are many variations and research trends in the flipped classroom mode, which can refer to [16-17].

There are also many research results about data structure teaching, and topics include the software tool and active-learning strategy [1], the learning motivation and retention effects of pair programming [2], the software engineering approach [3], the application of flipped classroom model [6], the application of course-oriented online judge [9], the collaborative learning tools [18], the teaching through group based collaborative peer interactions [19], the application of flipped classroom in experimental teaching [20], and so on. However, these articles either did not involve flipped classroom, or OJ or MOOC platform.

There are still some challenges in the flipped classroom teaching of data structure as follows:

- how to use information technology skillfully;
- how to make abstract theoretical knowledge easy to understand and micro lessons attractive;
- how to effectively stimulate students' autonomous inquiry learning and actively participate in communication and discussion;
- how to effectively improve the level of teachers' teaching theory and apply it to the flipped classroom teaching.

Therefore, we focus on the application of flipped classroom by considering both OJ and MOOC platform in data structure teaching. The OJ and its problems and the micro lessons on MOOC platform are self-made, which provide customized support for our students. The main contributions of this paper are summarized as follows. First, we design the flipped classroom teaching in data structure course based on self-made OJ and micro lessons on MOOC platform. Second, we discuss the arrangement of activities in the class under the flipped classroom model, which is corresponding to Bloom's cognitive learning

objectives. Third, we analytically investigate the effectiveness of this approach.

The rest of this paper is organized as follows. In Section 2, we introduce the flipped classroom. In Section 3, we discuss the application of flipped classroom in data structure. Effect analysis are explained in Section 4. This paper is concluded in Section 5.

## 2 Introduction of Flipped Classroom

The concept of flipped classroom was proposed by J. Wesley Baker in 2000 [4]. The practice of flipped classroom originated from two chemistry teachers (Jonathan Bergmann and Aaron Sams) of Woodland Park High School in 2007. In 2011, Salman Khan, the founder of Khan Academy, delivered a speech known as "Using video to recreate education" on TED (Technology Entertainment Design), which has aroused extensive attention, research and practice of flipped classroom. A basic flipped classroom model was introduced by Robert Talbert in 2011 [15], which can be described as Fig. 1.

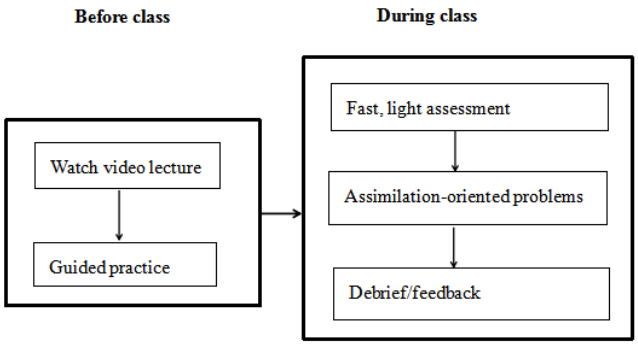


**Fig. 1.** Basic Flipped Classroom by Robert Talbert

In the basic flipped classroom model by Robert Talbert, the class was divided into two stages [15]: before and during class. In the first stage, the students watch video lecture, and then do some guided practice. In the second stage, the students do some fast and light assessments firstly, and then do the assimilation-oriented problems, and finally debrief and feedback.

Actually, a class can be divided into three stages: before, during and after class. It mainly includes knowledge imparting and knowledge internalization. Under the traditional teaching model, students preview what they learn before the class, teachers impart knowledge during the class, and students internalize knowledge through homework and other activities after class. While under the flipped classroom model, knowledge is imparted before the class through the MOOC or SPOC (Small Private Online Course) courses and other methods, knowledge internalization is done through homework, communication and guidance and other methods during the class. The comparison between flipped classroom model and traditional teaching model was discussed in [10, 16], which can be summarized as Table 1.

**Table 1.** Comparison between flipped classroom and traditional teaching model

| Item | Flipped classroom | Traditional teaching |
|---|---|---|
| Before class | Impart knowledge by using online micro lessons | Prepare lessons |
| During class | Internalize knowledge by homework, communication and so on | Impart knowledge by teachers |
| After class | Expand knowledge | Do homework |
| Students | Positive and active learners, cooperators and explorers | Passive listener and receiver |
| Teachers | Designers, tutors, and promoters of learning | Lecturer |
| Resources | Online micro lessons and other resources | Teaching material and references |
| Environment | MOOC/SPOC and offline classrooms | Offline classroom |

In the flipped classroom activities, students become positive and active learners, cooperators and explorers from passive receivers, while teachers change from imparting knowledge to promoting and guiding students' learning [5, 10]. Therefore, teachers need to align their teaching ideas with those of this model and make the teaching process from teaching-centered to learning-centered. Under such a teaching

model, teachers record what they will teach beforehand, students learn knowledge through the network before class, and the students internalize the knowledge through the classroom activities such as completing the homework, exchanging and discussing opinions under the guidance of the teacher. In order to make students interested in learning and the teaching approach effective, it is necessary to record micro lesson by employing information technology. The teacher-student interaction is the key to the flipped classroom model. Whether the internalization of knowledge is effective during the class is the main criterion to measure the effectiveness of this approach.

## 3 Application of Flipped Classroom in Data Structure

### 3.1 Instructional Design

Our flipped classroom teaching in Data structure is also divided into three stages: before, during and after class. Each stage involves the activities of the teacher and students, which are shown in Fig. 2. Before the class, teachers need to develop the learning objectives according to the six cognitive process levels of Bloom's Taxonomy [21], and give the to-do list. These six levels from lower order to higher order are: "remember", "understand", "apply", "analyze", "evaluate" and "create". The first three levels are lower order learning objectives, and the last three levels are higher order learning objectives, as shown in Fig. 3.

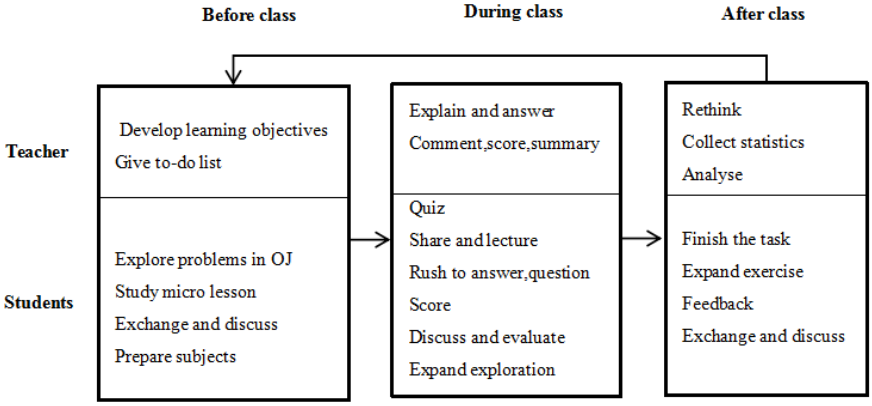


**Fig. 2.** Flipped classroom teaching in data structure

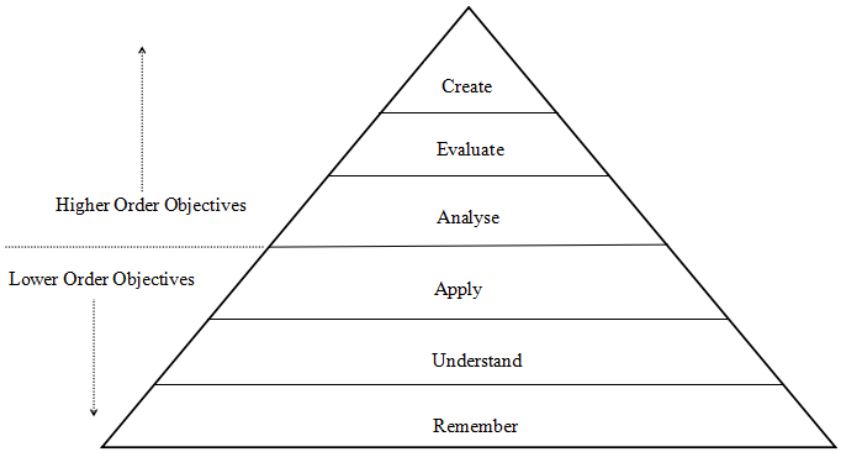


**Fig. 3.** Learning objectives in cognitive processes of Bloom's taxonomy

The to-do list includes learning objectives, knowledge needs to be learned for micro lesson, exercises and homework need to inquiry on OJ platform and other reading materials. Students try to meet the learning objectives according to to-do list, study through micro lessons and try to solve the problems on OJ platform. If they have questions, they can watch the teaching video repeatedly or have a discussion in the discussion area on MOOC platform, or through group chats on WeChat, QQ and so on. Students can

be divided into several study groups (3 to 5 students in one study group) to share opinions or raise questions. During the class, students should first take a quiz on knowledge which needs to be learned before the class on MOOC platform. Then the teacher or the students in the responsible group give a detailed lecture on important knowledge that is difficult to understand, and the teacher explain and answer questions according to students' discussion before class and quiz taken by students during the class. After that, teachers will randomly select the students of study groups to talk about or share the main points that need to be learned or have been done, or discuss the subjects of OJ problems (usually from OJ platform). The teacher can allow students in other study groups to answer, let them make a discussion on the difficult questions and main points, and allow other study groups to evaluate and grade the performance or to raise questions. Then, the teacher can grade their performance, make comments and a conclusion. Study groups can also make in-depth discussions on questions that baffle them within the group. After class, students complete after-class tasks through OJ platform, take extensive exercises requiring innovation, and give feedback and make discussion through MOOC platform and other communication tools. Furthermore, the teacher makes statistical analysis to students' learning, revamp and improve the teaching objectives and learning tasks.

### 3.2 Main Activities During the Class

The activities arranged for Data structure during the class under the flipped classroom model are based on what students learn through micro lessons on MOOC platform before the class and their discussion on questions on OJ platform. This kind of activities is the key to this teaching approach. Knowledge is internalized and more things are learned mainly through the activities of communication and discussion, groups sharing and giving lectures, and playing a game in which someone that puts up its hand first can answer the question, with the main aim to meet the higher order learning objectives in the cognitive domain of Bloom's Taxonomy. The main activities arranged during the class for Data structure under the flipped classroom model are introduced below.

#### Activity 1: Quiz in the class

Each quiz during the class is arranged on MOOC platform. It consists of five multiple-choice questions and takes 10 minutes to complete, with a total score of 10. The scores are considered as parts of the results of exam. The quiz mainly includes the questions about main points which can be answered correctly if student internalize the knowledge well before the class. This quiz is used to measure if students do a good job of previewing what to be learned before the class, achieve the lower order learning objectives in the cognitive domain of Bloom's Taxonomy, and to lay the groundwork for the next activity.

#### Activity 2: Explaining and answering questions

According to the teaching plan and students' quiz results, the teacher will explain the main points and the knowledge that is hard to understand, which can also be explained by the students in the responsible group. Also, the teacher (or the students in the responsible group) will give answers to the questions raised by students on MOOC platform, or other questions they have before the class, and help students with their study according to their specific situation. This activity aims to meet lower (for the students have questions) and higher (for the students in the responsible group) order learning objectives in the cognitive domain of Bloom's Taxonomy.

#### Activity 3: Sharing, lecturing and questioning

Before the sharing and lecturing, an application is used to randomly select a study group to give a speech on a topic and raise questions that need to be answered by other study groups. Teachers can also put forward some questions to guide the students to think about and to be answered by them. In order to make students interested in the game in which someone that puts its hands first can answer one question, students will score 1 point if they answer a question correctly. Other study groups can also question what is said by the group that gives the speech, to make both sides to debate. This activity aims to achieve higher order learning objectives in the cognitive domain of Bloom's Taxonomy.

Activity 4: Discussion, analysis and evaluation

Each study group can give opinions and evaluations on the approach or method that is used to figure out what baffles them or other problems they discuss, which can come from past programming contests, other problems on OJ platform, and comprehensive problems such as "Tourism planning", which is a shortest path problem for dual constraints, to promote learning, exchanging opinions and discussions, and to carry out the analysis to the different methods. This activity aims to achieve higher order learning objectives in the cognitive domain of Bloom's Taxonomy.

## 4 Effect Analysis

As for the final score for data structure, the result includes the online and offline results, and it is divided into several process assessments and final exam. Let *fs, es, pas,* and *as* denote the final score, end-of-term score, process assessments score, and additional score (e.g. score from programming contests) respectively, the calculation of the final score can be expressed as equation (1).

$$fs = \min\left(es \times 50\% + pas \times 50\% + as, 99\right) \tag{1}$$

where "min" means to take the minimum value, and 99 is the maximum score.

The process assessments include the scores for online programming assignments on OJ and classroom performance, midterm score, experiment score, and online scores on MOOC platform. Students' performance on MOOC platform is graded by evaluating many aspects, which include watching micro lessons, taking quizzes and tests, finishing homework, posting messages and giving replies in the discussion area. The composition of process assessments is shown in Table 2. The composition of online scores on MOOC platform is shown in Table 3.

**Table 2.** Composition of process assessments

| Item | Occupation |
|---|---|
| programming assignments | 5% |
| classroom performance | 5% |
| midterm score | 5% |
| experiment score | 10% |
| online scores on MOOC platform | 25% |

**Table 3.** Composition of online scores on MOOC platform

| Item | Occupation |
|---|---|
| watching micro lessons | 20% |
| quizzes | 25% |
| tests | 10% |
| homework | 25% |
| discussion | 20% |

Although we once used the flipped classroom model to teach parts of the Data structure for 2018 students (students who were enrolled in 2018) and before, our teaching approach at that time was still teaching-centered. When we began to teach 2019 students (students who were enrolled in 2019), we tried to improve the current micro lessons which include algorithm application and algorithm design, providing support for students' personalized learning. Hence, most of the contents can be taught through the flipped classroom model. Table 4 shows the comparison of the end-of-term score between the third class (Class 193) of 2019 students and the second class (Class 182) of 2018 students. As shown in Table 4, the excellent rate increases by 19.5%, while the failure rate decreases by 22.2%. That is, the final exam results of 2019 students who were taught by the flipped classroom model are better than those of 2018 students who were taught by the traditional teaching method. It can be seen that the flipped classroom model produces good effects on teaching.

**Table 4.** Comparison of the end-of-term score

| Class | Scores in [80, 99] | Scores in [60, 79] | Scores under 60 |
|---|---|---|---|
| Class 193 | 58.0% | 36.0% | 6.0% |
| Class 182 | 38.5% | 33.3% | 28.2% |

## 5 Conclusion

The teaching practice for data structure shows that the flipped classroom model makes students become the main actors in the class and can produce positive effects on teaching. The flipped classroom teaching of data structure can improve students' learning autonomy and enthusiasm, and highlight "learning as the center", which can effectively improve the achievement of teaching objectives, as shown in Table 5.In addition, the arrangement of classroom activities in the flipped classroom teaching of data structure is also conducive to the achievement of Bloom's cognitive objectives, as shown in Table 6.

**Table 5.** Comparison of the achievement degree of teaching objectives

| Class | Knowledge objectives | Capability objectives | Quality objectives |
|---|---|---|---|
| Class 193 | 91% | 65% | 88% |
| Class 182 | 78% | 50% | 62% |

**Table 6.** Achievement degree of learning objectives in the cognitive domain of Bloom's Taxonomy

| Level | Average achievement degree |
|---|---|
| Remember | 95% |
| Understand | 87% |
| Apply | 76% |
| Analyze | 69% |
| Evaluate | 51% |
| Create | 24% |

From Table 6, we can observe that the achievement degrees of higher learning objectives in the cognitive domain of Bloom's Taxonomy are not so good. We will make further analysis and research to improve achievement degree of higher learning objectives in the future.

For the future teaching with such approach, teachers need to solve such problems as how to effectively instruct slow learners and make the class more innovative for meeting higher order learning objectives, and then make the class challenging as a way to develop first-class courses.

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