Engineering Ability Construction in Flipped Classroom Teaching Approach

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Abstract. Engineering ability is an important quality for college and university graduates majoring in engineering. Flipped classroom is an effective teaching mode, which has been widely used in colleges and universities. How to cultivating engineering ability in the process of flipped classroom teaching is an important problem. This paper considered the approach of engineering ability training, and discussed the requirements of flipped classroom in the aspects of curriculum goal, teaching process organization, teaching platform and evaluation system. The main major courses for undergraduates in specialties of Big Data is used to illustrate the approach. The results show that the proposed architecture and method are effective.

Keywords: Engineering ability · Flipped Classroom · Teaching process organization · Evaluation system

1 Introduction

Engineering ability is the foundation of human social progress to respect the natural law and social norms, the ability to use tools to carry out productive activities and create material wealth on the basis of understanding nature. For engineering college students, engineering ability is the ability to learn and apply professional knowledge, analyze and solve problems under the constraints of comprehensive consideration of laws and regulations, professional norms and social sustainable development, and having appropriate engineering ability is the most important training goal in the university stage [1]. Today, the accreditation represented by the *Washington Accords* is the most common international standard in engineering education. China became a regular member of the *Washington Accords* in 2016. Engineering accreditation emphasizes the whole process and the requirement of full coverage for all students' engineering ability training, and the school needs to review the working methods and results evaluation mechanism of each link, especially the teaching link [2]. In recent years, the research on the cultivation of engineering ability has been paid close attention to by many scholars, and more than 120 journal articles have been published during 2017 and 2018.

According to the *Engineering Education Accreditation Standard*, engineering graduates must have the ability to solve complex engineering problems [3]. This requires that students should be able to consider the solution of the problem in general,

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including multi-disciplinary cross-cutting, as well as economic, social, sustainable development and other factors, not just the application of this professional technology [4]. How to cultivate students' ability to solve complex engineering problems in the course of teaching has become an important issue in the process of teaching organization, planning and implementation [5]. Reference [6] studies how to cultivate engineering ability in CDIO environment, Reference [7] discusses the reform of teaching methods oriented to the cultivation of engineering ability, and carries out the corresponding practice.

Based on the complexity of engineering ability cultivation, constructivist learning theory centered on learner individual provides scientific guidance to relevant teaching organizations [8]. Flipped Classroom is a teaching organization method based on Constructivism, which is a student-centered, through pre-class, in-class and after several stages of learning to complete the knowledge of the internal, its main purpose is to enhance students' self-learning ability, so as to better build the knowledge system [9]. The Teaching organization form of flipped classroom has been widely used in universities [10]. Many universities in the United States, especially higher engineering colleges, have begun to apply flipped classrooms for teaching organization, and have been recognized by teachers and students, which is considered to be a good way of teaching organization [11]. Domestic universities also began to apply flipped classroom, and combined with information technology to build a network teaching platform [12]. The teaching idea of student-centered, problem-oriented and encouraging practice in the process of flipped classroom teaching coincides with the requirements of the cultivation of engineering ability [13]. Therefore, it is an effective form to use Flipped classroom teaching method to cultivate students' engineering ability. However, in the practical application, the teaching organization method based on flipped classroom also exposes some problems in cultivating students' engineering ability, which needs to be further perfected in the aspects of teaching goal, teaching process organization, teaching platform and evaluation standard.

2 Current Problems

2.1 Lack of Quantitative Analysis of Engineering Capabilities, Take Knowledge Transfer Instead of Capacity Training Goals

The output standards set out here including 12 points: 1. Engineering knowledge, 2. Problem analysis, 3. Design and development solutions, 4. Research, 5. Using modern tools, 6. Engineering and social, 7. Environmental and sustainability, 8. Career norms, 9. Personal and team, 10. Communication, 11. Project management and 12. Lifelong learning. The cultivation of engineering ability objectively requires students to have more comprehensive ability, not only to have theoretical knowledge in professional field. This requires quantitative analysis of the content of the curriculum in the formulation of teaching objectives, and the identification of capacity development objectives, otherwise it will not be possible to adapt to this new environment. On the other hand, the cultivation of ability needs the support of the whole curriculum system, in the specific formulation of curriculum plan, it is necessary to design the curriculum

and engineering ability Training target matrix, so that the curriculum and engineering ability requirements correspond, that is, with the training objectives of students, and then targeted curriculum content and teaching organization form design.

2.2 In the Teaching Process Organization Along the Traditional Teaching Habits, Flipped Classroom Effect Is not Fit

Although there have been many cases of flipped classroom application in China, it is not satisfactory in practical application, one of the important reasons is that traditional teaching habit has a strong psychological basis and practical feasibility among teachers and students, and this change of habit is not a slogan or a scheme can be completed. Flipped classroom education concept of *Student-centered* and *Active learning* in the actual operation process is very bony. Reference [14] analyzes the causes of this problem from the aspect of *field-habit* theory, and points out that because of the characteristics of students' and teachers' heterogeneity, The failure of flipped classroom has its internal reasons, it is necessary to construct a new form of teaching organization.

2.3 It Is Necessary to Combine Modern IT Technology to Build a Flipped Classroom Platform

Online learning platform, such as MOOC (massive open online courses), is a teaching aid that has been widely concerned in recent years, and has become an important carrier of the process of pre-class learning and after-school learning in the classroom. However, there are also problems in the application of the platform, such as passive acceptance, poor interactivity and inflexible feedback, many times the online learning platform is only a place for video playback tools and online operations, and does not provide better support for flipped classroom. With the advent of "Internet +" society, we should make full use of mobile computing technology to put forward new solutions, in order to achieve the teacher can lay the task on demand, check the completion of the situation, answer questions, organize student discussions, expand the limited classroom to unlimited space and time, to achieve all-weather.

2.4 It Is Necessary to Establish a Scientific Flipped Classroom Evaluation System, and Change the Knowledge Assessment to the Ability Assessment

According to the decomposition of curriculum engineering ability, improve the curriculum assessment mechanism, establish an objective flipped classroom evaluation system in line with the requirements of engineering accreditation, instead of the traditional examination form. The examination will run through the whole process of flipping the classroom, forming the evaluation system of the process assessment and final appraisal. Combining the training process of engineering ability with the result of students' assessment, it is directly linked with the student's grade, and the assessment of knowledge point is changed into the assessment of ability, which solves the problems existing in the traditional evaluation system. This kind of assessment will also transform the students' learning style, in order to promote the students to take the

ability training as the focus of learning, improve the initiative and purpose of learning. Through the calculation of the degree of achievement, the various ability components are aggregated to form the comprehensive ability evaluation of students.

3 Curriculum Groups Setting and Analysis of Ability Indicator Point

3.1 Curriculum Groups Setting

The cultivation of engineering ability has a strong comprehensive, it is necessary to consider the correlation of relevant professional knowledge and ability requirements, not only the intersection between different disciplines, but also to consider the sequential relationship between courses and the integration of knowledge in the same subject, and the setting of curriculum group is based on this principle. Data science and big data program curriculum are professional courses, including Big Data Foundation, cloud computing Framework, Python, MapReduce Design Patterns, NoSql database, R language data mining, Spark programming and other theoretical courses and corresponding practical links. The teaching goal of the curriculum group is to adapt to the trend of technological development and the demand of information industry, to train Big Data engineer processing and Big Data analysis engineer, and the courses are interrelated and progressive, forming logical relations, causality, and composing knowledge system. The course group is offered in the field of computer science and technology, and the first courses include discrete mathematics, computational composition principle, operating system, computer network, data structure, programming Foundation, database and software engineering and other computer majors. Through the study of this kind of course, students can fully understand the basic knowledge of data science and big data, cultivate the ability of building and developing big data system and data processing and analysis, adapt to the needs of big data engineers at present and in the future, and have the ability of self-learning and renewal.

3.2 Quantitative Analysis of Competency Training Objectives

The E-learning environment in the learning system or architecture is based on an online learning platform, which is composed of co-operative learning and question-answer system.

Engineering accreditation determines the standard of personnel training by equivalence evaluation, which clearly requires students to have 12 engineering capabilities, including not only engineering knowledge, but also humanities, society, law and personal development. For the course teaching organization, we must first determine the ability requirement matrix of the course, and then can organize the corresponding teaching activities.

Through the research on the general standard of engineering accreditation and the supplementary standard of computer science and technology, combined with the specific contents of data science and big data program curriculum, the ability training

target matrix of this curriculum group is developed within the framework of the overall training goal of computer specialty.

After intensive analysis, the engineering ability indicators corresponding to the data science and big data program curriculum are shown in Table 1.

Table 1. Engineering ability indicators for the major of data science and big data.

No.	Name	Sub-criteria	Description
1.	Engineering knowledge	1-1	It can carry out abstract thinking and apply knowledge of mathematics and natural sciences to the representation of computer engineering problems such as large data information processing
		1-4	Familiar to the process of analysis, design, development and implementation of large data information processing system, and can be properly applied in practice according to the problems
2.	Analysis	2-2	By means of literature search and data analysis, the nature and characteristics of complex large data engineering problems can be analyzed by combining the principles of mathematics, natural science and professional knowledge, and effective conclusions can be drawn
		2-3	It can model the solution, construct a prototype system based on computing principle, and analyze its rationality
3.	Design	3-1	It can carry out research on large data information processing engineering problems and clarify relevant constraints, and complete requirement analysis for computer hardware and software systems
		3-2	It can design and implement algorithms for specific large data information processing requirements, and test and verify the correctness of algorithms and programs
		3-3	It can take social, health, safety, legal, cultural and environmental factors into account in the design of large data information processing system, and make a comprehensive analysis of the above aspects, so as to improve the scheme
4.	Research	4-1	Guiding research by computational thinking can accomplish abstraction from practical problems to theoretical problems of computer science, or formalize theoretical problems of computer science by means of mathematical tools
		4-2	It can use mathematical and computer expertise and technical means to design and demonstrate the feasibility of the experimental scheme for the specific problems of large data information processing
		4-3	It can construct a large data information processing experimental system, carry out experiments, collect experimental data, and draw reasonable conclusions by analyzing the data
5.	Using modern tools	5-1	It can reasonably select, use or develop appropriate technologies, tools and resources in the field of large data information processing
		5-2	To meet the needs of analysis, design, development, operation and system maintenance of large data information processing system, we can choose appropriate methods and understand their scope of application or limitations

(*continued*)

Table 1. (*continued*)

No.	Name	Sub-criteria	Description
9.	Individual and team	9-2	Be able to integrate into the team and take on the corresponding roles in the work
10.	Communication	10-2	With an international perspective, understand the status and trends of data science and big data development, and can effectively communicate and communicate with peers and the public
12.	Self-learning	12-2	Master the method of self-learning and the way to expand knowledge and improve ability, and have the ability of self-improvement

In the process of teaching preparation of data science and big data program curriculum, a complete teaching file is developed, including syllabus, experiment outline, practice outline, teaching calendar, lesson plan, etc., these teaching files are the guiding documents to carry out teaching activities. Also prepared to assist students to learn a variety of teaching resources, including video, documentation, PPT, exercises, quizzes, etc., these resources through the online learning platform to provide students, to ensure that students in the flip class at all stages of learning.

4 The Teaching Process Organization of Flipped Classroom

4.1 Flipped Classroom Teaching Mode

The Flipped classroom teaching link is divided into three stages of pre-class study, in-class study and after-school study. The construction of engineering ability is a complex, comprehensive and gradual process, which completes different learning tasks through three stages of flipping the classroom, and satisfies the relevant requirements of engineering ability training.

The overall framework is shown in Fig. 1.

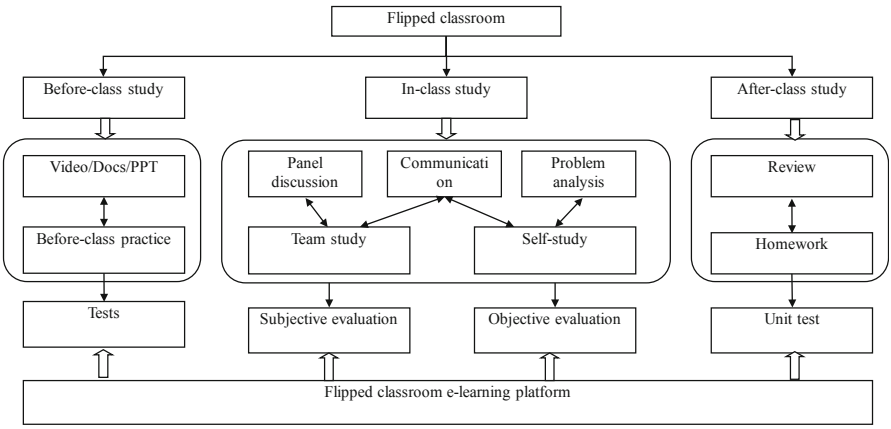

Fig. 1. Framework of flipped classroom

Pre-class tasks are mainly for students to watch video and other online resources, mainly self-learning, supplemented by appropriate pre-class exercises and quizzes, through self-study to complete the localization of knowledge. The ability of pre-class learning cultivation mainly includes 1. Engineering knowledge and 12. Lifelong learning, including 1-1, 1-4 and 12-2.

In-class tasks include classroom lectures, cases, discussions, exchanges, etc., and team collaboration training and evaluation. In order to complete the localization of classroom knowledge, the discussion and communication are carried out on the basis of studying engineering knowledge before class. The ability of learning and training in class mainly includes 2. Problem analysis, 4. Research, 9. Individuals and teams and 10. Communication, including 2-2, 2-3, 4-1, 4-2, 4-3, 9-2 and 10-2.

After-school tasks include after-school exercises, reviews, applications and quizzes, the main goal is to complete the localization of knowledge through application and practice. The ability to cultivate after-school learning mainly includes 3. Design/Development solutions, 5. Using modern tools, including 3-1, 3-2, 3-3, 5-1 and 5-2.

In this way, through three stages of learning, the use of pre-class learning, in-class discussion and after-school application of the model to complete the process of knowledge, the realization of student-centered, internal driving force as the leading learning mode. The evaluation results of all these stages are counted in the final general comment, and the final learning evaluation of the course is given.

4.2 Teaching Process Organization

Flipped classroom is a student-centered teaching model, but there are unsuitable situations both at the teacher's end and on the student side. Teachers send videos, documents and so on to students, and leave a large number of exercises for students to do, as a basis for students to self-study, that the realization of the main school supervisors from the teaching of the transformation; But students do not adapt to this way, no motivation to take the initiative to learn, leading to self-relaxation, the result is good students effect is good, poor students have poor effect, did not play the desired role.

In view of this problem, the following ways are adopted to solve.

First, on the basis of full research to consider the proportion of teachers and students to do, for the data science and big data program curriculum of the curriculum, to determine the overall proportion of the two is about 4:6, and there are differences between different content proportions. As the content of the introduction and concept appropriately increases the proportion of lectures, and the practical content increases the proportion of students.

The second is the use of task-driven Flipped classroom organization form. Task-driven is one of the constructivist learning methods, which realizes the transformation from knowledge to ability by completing tasks. The greatest benefit of task-driven is the integration of textbook abstract, fragmented knowledge in a unified form, encompassing both integration within the same course and integration between different courses. For example, in task design, students are required to use web crawler technology for a hit film in the domestic well-known video review site to obtain data, processing data, complete word frequency analysis. This task applies Hadoop cluster

technology, Python program design, and MapReduce programming techniques, and involves three courses, such as *Big Data Basics*, *Python Language*, and *MapReduce Design Patterns*.

Third, adopt a team-based learning model. Team learning has two advantages, one is through the team's internal collaboration and mutual assistance, give full play to their respective advantages, complement each other, promote each other; Second, through the competition between the team, so that all participating students have upward learning driving force, change passive learning for active learning. In the specific implementation, first determine the number of groups, by a group of 4–6 people, thus ensuring that the organization can form an atmosphere of cooperation and discussion, as well as individual isolation due to the large number of persons. Secondly, the members in the group are determined, and the principle of combining stochastic allocation with voluntary team formation is adopted. According to the student's comprehensive achievement point ranking in the previous year, the number of groups ranked the top students as the team leader of each group, other students in a voluntary principle according to the way of choice to join one of the groups. Such grouping can avoid the psychological discomfort of completely random grouping and the *good students piling* phenomenon that may result from full voluntary grouping, and strike a balance to the learning ability of each group of members to the greatest extent.

In classroom teaching, two scoring strategies are adopted according to the different tasks, first, according to the number of students in the group completing the tasks to score; the second is to compete between the groups, according to the rankings to score. After each class in the teaching platform to publish the scores of each group, so that students timely understanding of the status of each group, enhance the sense of competition and promote learning. At the end of the semester, the scores of each group were counted, and the group with the highest scores was recorded as excellent (according to the current school regulations, excellent corresponding to the percentile of 95 points, other levels and so on), the scores of the other groups are calculated based on the relative ratio of the group with the highest score.

Practice shows that this kind of team classroom organization way has achieved good results. Students are active to answer questions, timely to submit homework, students in the group to help each other to solve problems, so that the classroom atmosphere unprecedented active, learning enthusiasm has been greatly improved, even students who do not do well can be integrated into the team to play a self-role, to meet the individual and team ability to develop the requirements.

5 Using Mobile Computing Technology to Build Flipped Classroom Learning Platform

In order to realize flipped classroom teaching and make use of Internet technology and multimedia technology, many schools have built an online teaching system based on MOOC. Such systems provide a wealth of teaching resources, while supporting teachers to set up their own courses on the platform, upload homemade courseware as needed, and provide student management, online assignments, exams, grade management, posting discussions, as well as students' learning behavior records and

statistical analysis, which provide convenience for flipping classroom teaching. However, such systems also have poor communication, cannot send notifications in a timely manner and participate in discussions and other issues. Instant Messaging (IM), represented by QQ and WeChat, has spread across all corners of society, especially with the popularity of smartphones, IM has become a way of life. In the college student community, the penetration rate of smartphones has exceeded 100% (some students have more than one mobile phone). Therefore, leveraging the advantages of smartphones and IM, making full use of fragmentation time, combining system learning with fragmented learning will be an effective means of learning [15].

In the process of data science and big data program curriculum teaching, using online teaching system and IM complement each other to give full play to the advantages of the two, so that the flipped classroom teaching effect is better. Before the start of the course, the course is offered in the online teaching system that has been built in the school (currently selected as a company's cloud network teaching platform), the establishment of classes, the introduction of student rosters, and then the setting of knowledge points according to the requirements of the syllabus, the production of learning materials for each knowledge point, such as video, documentation, PPT, etc., students can log in to pre-class learning, and can record students' learning behavior, such as the number of times to watch the video, time duration, ruminant ratio, etc., so as to understand the input of students learning, but also the use of statistical functions to output student performance.

In IM (Instant Messaging), such as QQ, to establish a curriculum group, group name for semester + courses, such as *2017 Autumn 15 big data foundation*, the monitor will take all the students into the group, in the form of group announcements to issue a variety of notices. When learning in class, make full use of group functions, such as group files, discussions, voting, etc., to achieve instant information sharing, updates and feedback. The previous hands to speak, manual statistics and other work to be completed by the functions provided by IM, such as the form of group voting statistics of students on a certain issue or evaluation of a certain discussion, so as to achieve a combination of knowledge systematization and fragmentation of the new learning environment. At the same time, in this environment, teachers can be an organizer to mobilize students to participate.

In the after-school learning stage, the online teaching platform can publish assignments, conduct tests, and evaluate students' learning achievements. IM can be used for answering questions, discussing, or posting small questions, such as views on answers to a question, comments, and even single-choice and multi-choice forms in the form of a vote. It can make full use of fragmented time to arrange learning activities, the past can only fixed time, fixed location of teaching activities into anytime, anywhere, ubiquitous classroom, so as to complete the process of capacity construction after class.

6 Competency-Based Evaluation System

In traditional teaching process, the evaluation of students is mainly based on the mastery of knowledge, even if the assessment of the way of reform, essentially only increased the number of test examination, in most cases did not highlight the requirements of the ability assessment. The result is that the engineering knowledge part of the paper assessment is easy to evaluate when the achievement is calculated, while other abilities are not well measured. In order to solve this problem, the ability evaluation system is established in the teaching of data science and big data program curriculum.

The ability evaluation criteria are shown in Table 2.

Table 2. Ability evaluation criteria

Grade	Description
A	Ability to lead team; solid knowledge of data science and big data engineering; leading role in scheme design; core member of system development and implementation; strong research ability; proficiency in tool use; initiative to learn relevant knowledge, familiar with the development of big data information processing technology
B	Be a backbone member of the team; be familiar with data science and big data engineering knowledge; play a secondary role in scheme design; be an important member of system development and implementation; have strong research ability; be familiar with tool use; be able to learn relevant knowledge by oneself and understand the development of big data information processing technology
C	Be able to integrate into team; master data science and big data engineering knowledge; be able to complete responsible project design; be a member of system development and implementation; have research ability; be able to use tools; be able to learn relevant knowledge and understand the development of large data information processing technology as required

In the normal process examination, the evaluation criteria are used to evaluate the students. On the basis of the above team score, the team members are assessed in the form of mutual evaluation, and the assessment ratio is set to: A 20%, B 40%, and C 40%. The assessment level and the team score multiplication is the individual process ability assessment score, this part of the score and the final Test score added to get the personal total score. The evaluation mechanism in the group effectively promotes the benign competition among the students in the same group, embodies the value of learning and guarantees the fairness.

7 Conclusion

Aiming at the demand of engineering ability training for teaching organization form, this paper studies and practices the teaching organization mode of flipped classroom applied in engineering teaching. This paper discusses the curriculum goal of flipped classroom, the organization of teaching process, the construction of teaching platform and the evaluation system. In the teaching process of undergraduate data science and big data program curriculum, all aspects of flipped classroom are verified. The analysis shows that this kind of teaching organization satisfies the requirement of engineering ability cultivation, and the investigation feedback to students also shows that this way is effective to improve the ability.

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