A Proposed Flipped Project-Based Flipped Classroom for Teaching in College Large Classes

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Abstract—**The adoption of the flipped classroom in the lower grades of the university encounters several practical challenges within the context of the new engineering education objective. These challenges include the considerable student population, student reticence, and the facilitation of high-order cognitive skills. This study proposes a flipped project design mode and teaching activity design framework that addresses the practical challenges faced by the flipped classroom. Transforming the existing class discussion project into a student-led class project that possesses the capacity for generation, expansion, and exhibits a robust cross-disciplinary, creative, and dynamic nature. The enhancement of student involvement and participation can be greatly achieved through collaborative efforts between teachers and students. Four teaching interactions encompassing co-planning by the teacher and students, interaction between students within the group, interaction between students between groups and communication between the teacher and students are organically cross-integrated, resulting in the implementation of student-centered flipped classroom teaching through a dynamic competitive approach. The studies show that the flipped classroom approach, as implemented by the flipped project, helps actively engaged students develop high-order cognitive skills and improve learning efficiency. This educational strategy can motivate and inform passive learners to enhance refactoring skills, create a multi-dimensional knowledge tree system, and improve learning efficiency.**

Keywords—**flipped classroom, large class teaching, knowledge integration, high-order thinking**

I. Introduction

The education realm is currently facing unprecedented challenges as a result of the Fourth Industrial Revolution. One notable development was the publication of “The Global State of the Art in Engineering Education”, which has prompted numerous countries to undertake education reforms using a range of different approaches and perspectives [1–3]. The “New Engineering Education Transformation” initiative initiated at Massachusetts Institute of Technology (MIT) highlights the imperative of educational methodologies that cultivate students’ recognition of fundamental knowledge and their proficiency in effectively navigating the ever-evolving developments in science and technology, thereby empowering them to emerge as pioneers and investigators [4–6]. China is also actively pursuing reforms in higher education, particularly in the field of engineering education, under the framework of the Fourth Industrial Revolution [7]. Since 2017, China has implemented comprehensive reforms of new engineering education, employing systematic approaches consisting of multiple stages [8]. Anyway, the objective of the new engineering education is to cultivate a cohort of inventive engineers who possess the ability to swiftly acclimate to novel circumstances and fluctuations [9–14].

The implementation of a flipped classroom teaching model has been commonly observed in numerous university courses, with the intention of fostering the development of high-order thinking skills. The impact of flipping the classroom was notably pronounced in the context of small class sizes [15]. However, the utilization of this approach in the instruction of large classrooms at lower grade levels is accompanied by various practical challenges. The prevailing instructional approach in computer science education, particularly in universities with significant student enrollments, continues to center around large-class lectures. This pedagogical mode remains consistent across both general and specialized facets of the field [16, 17].

This paper began by discussing the implementation of the flipped classroom approach as a means to address the challenge at hand. The classroom project was transformed into a real-time assignment, using traits such as scalability, transformability, and dynamic growth to effectively resolve this conundrum. The cooperative game format was utilized to foster student engagement, while active learning and high-order thinking were facilitated through brief classroom presentations, task creation, and problem analysis. These activities contribute to the independent reconstruction and integration of knowledge by students.

II. Project Requirements

In order to enhance students’ capacity to promptly adapt to novel circumstances and modifications, it is imperative that classroom projects possess the attributes of dynamic variability. In line with the pedagogical

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approach of flipped classrooms, which aims to transform students' learning experiences, it is also possible to adopt a flipped model for classroom projects. This entails shifting the role of project producers from teachers to students. It is recommended to foster the active participation of all students in the developmental process of a shared project, wherein regular updates are made to the project in an iterative way, leading to a dynamic evolution of its content. Students will consistently establish fresh objectives for their own personal development. Classroom projects offer students the opportunity to engage in self-directed inquiry and learning, fostering the development of perceptual autonomy and enhancing motivation for learning.

As depicted in Fig. 1, the instructor disseminated the initial conventional project p, which was subsequently divided by the students into n subtasks p_1, p_2, ..., p_n. These subtasks were then addressed individually, resulting in answers for each respective subtask. Ultimately, the aforementioned solutions were integrated in order to generate the comprehensive solution for the initial project.

$$p = p_1 + p_2 + p_3 + \ldots + p_n \tag{1}$$

In the context of the flipped project, the instructor initiates a preliminary project, denoted as p, which serves as a solid basis. Subsequently, the students undertake the task of independently modifying this project by incorporating n design elements, referred to as p_1, p_2, ..., p_n. Ultimately, this process culminates in the creation of one or more extended projects, denoted as p_{new}.

$$p + (p_1 + p_2 + p_3 + \ldots + p_n) = p_{new} \tag{2}$$

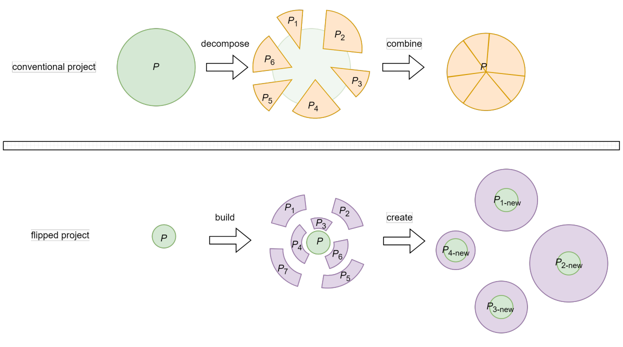

Fig. 1. The difference between a flipped project and a conventional project.

III. Flipped Project-Based Flipped Classroom

In order to enhance the qualities associated with large class teaching, this section proposes several recommendations and effective strategies in three key areas: teaching interaction, flipped projects, and teaching process. These suggestions aim to enhance the quality of flipped classroom teaching and contribute to the advancement of educational and teaching reforms in similar courses.

A. Teaching Interaction

The flipped classroom should include four teaching interactions that are mutually compatible and collectively contribute to the overall instructional process.

Firstly, teacher-student shared decision-making interaction. In accordance with the learning scenario, the educator selects a series of assignments suitable for implementing the flipped teaching. At the commencement of the flipped classroom, students engage in a democratic process by either voting or raising their hands to ascertain the specific learning objectives that will be pursued during the course. During this interaction, students have the opportunity to engage in project comparison, actively assess project complexity, and make informed decisions about tasks that align with their abilities. Simultaneously, teachers can provide guidance by selecting tasks that reflect changes in the learning environment. The implementation of student autonomy in project selection serves as a fundamental component in establishing a student-centered learning environment. This interaction aims to instill in students the belief that they possess the capacity to make significant decisions within the educational setting, thereby addressing their intrinsic motivation for autonomy.

Secondly, interaction within group. Learners engage in verbal exchanges, deliberations, negotiations, and mutual assistance within a learning cohort, or they engage in cooperative efforts on course reporting tasks to cultivate shared knowledge and enhance their aptitude for communication and teamwork. By utilizing this group format, students are more likely to develop a sense of connection with their peers, instructors, and the subject matter, so effectively satisfying the requirements for intrinsic motivation. To cultivate the students' prompt response and execution skills, a division of labor system is implemented within the group, which is documented and presented.

Thirdly, interaction between groups. The incorporation of intergroup competition and continuous evaluation of each group's project contribution necessitates ongoing deliberations and decision-making within each group. As the volume of information expands, it also fosters ongoing ideation and creative thinking. To attain group success, each member will actively participate in conducting comparative analysis and engaging in high-order cognitive activities. Competition not only fulfills the external regulatory aspect of extrinsic motivation, but also enhances the recognition regulatory aspect. The students within the collective assert that their occupation is congruent with their personal beliefs or objectives, which can be comprehended as a form of motivation associated with regulating their identity. Given its profound internalization, this specific form of motivation is vulnerable to external influences, such as inter-group competition. As a result, it is probable that students' relative autonomy will be augmented, consequently raising the probability of transitioning from extrinsic drive to intrinsic motivation. Within the realm of cognitive processes, low-order thinking pertains to cognitive activities characterized by rudimentary or surface-level mental engagement. For students, heightened task involvement will yield improved quality.

Lastly, interaction between students and teachers. The objective of this interaction is to consistently enhance students' intrinsic motivation for achievement while simultaneously addressing learners' psychological needs for competence through external performance that can fulfill specified goals. Concurrently, educators have the capacity to allocate additional time towards addressing students' inquiries and guiding them towards activities that promote high-order thinking skills by tailoring instruction to their individual abilities.

These four links are interconnected, dynamically interacting, and progressing synergistically. As seen in Fig. 2.

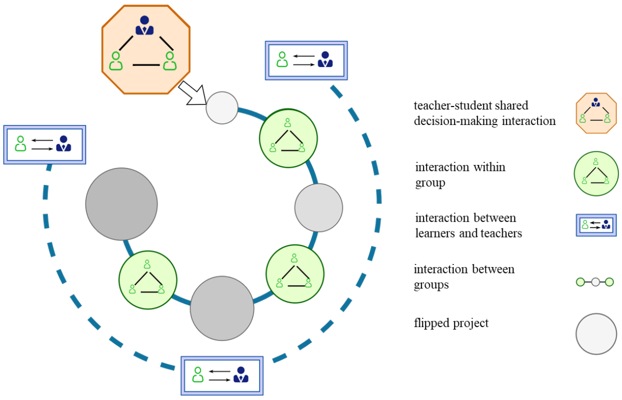

Fig. 2. Interaction design of flipped project-based flipped classroom teaching in large class.

B. Flipped Project

As previously mentioned, it is recommended that educators develop a pre-determined list of projects for their classes. These projects should be designed to align with the essential characteristics of the course, ensuring that the majority of students are capable of successfully completing them based on their acquired knowledge. For the initial project, students are required to select one option. Subsequently, the instructor directs the students to modify the initial assignment by engaging in divergent thinking or engaging in a brainstorming session. Students have the option to either transform the first project into a novel undertaking or introduce further modifications to the subsequent project that has been completed by their peers. The aforementioned process is capable of being replicated. The modifications made to each project should not be too extensive or overly intricate. Additionally, students are required to provide a justification for the design choices, as well as articulate their ideas or proposed alternatives. After undergoing multiple iterations, the initial project will inevitably transform into a project that is entirely devised by the students, so shifting away from its original teacher-led nature. The aforementioned approach to project construction, which prioritizes student-centered learning, is commonly referred to as a flipped project.

The implementation of flipped projects necessitates the amalgamation of foundational knowledge, concepts, connotations, and principles with interdisciplinary knowledge integration and multifaceted inventive learning. The instructional approach is deliberately designed to merge fundamental learning techniques with advanced learning principles, thereby enabling a sequential and progressive advancement. Students may encounter fatigue and academic burnout when the ultimate objective is excessively demanding, rendering the attainment of established goals within a reasonable timeframe arduous. As a result, this can have an adverse effect on their motivation towards the educational endeavor. When objectives are set at a lower level, the educational process becomes focused on acquiring fundamental knowledge, impeding the capacity for substantial advancement. Consequently, the cultivation of inventive thinking and advanced abilities is not sufficiently nurtured. Hence, it is crucial to proficiently integrate these two elements, thereby generating the optimal zone for development and the readily attainable zone for learning. Moreover, flipped projects should possess ample adaptability to cater to the personalized learning needs of every student, bolster their knowledge base, foster the growth of their cognitive faculties, facilitate the cultivation of advanced thinking skills, and promote engagement in activities that entail advanced thinking.

C. Teaching Process

The central focus of the flipped classroom teaching process is the student, with its foundation rooted in flipped projects. It is recommended that all students establish their own groups, with a limited number of members in each group. Once the project is initiated through a collaborative decision made by students and teachers, competition rules are established, a competitive environment is created, and reasonable winning conditions are defined. Subsequently, each group allocates tasks to individual members in accordance with the prescribed activity guidelines. In order to enhance the level of excitement and anticipation inside the competition, the subsequent group assigned with the task of expanding projects is selected by a random process. Then the design point or contribution point to be added to the existing flipped project will be determined within a limited timeframe by the selected group that has thoroughly taken into consideration the extension possibilities of the flipped project. One member of this group will be chosen through a random selection method to explicate and demonstrate the decision made by the group, while the remaining groups will attentively observe and assess. The fate of the group, namely whether it will be eliminated or not, is contingent upon a collective decision-making process involving the participation of all groups in voting to determine. The duration of the competition activity may be adjusted in accordance with the duration of the class hour. Fig. 3 illustrates the full method.

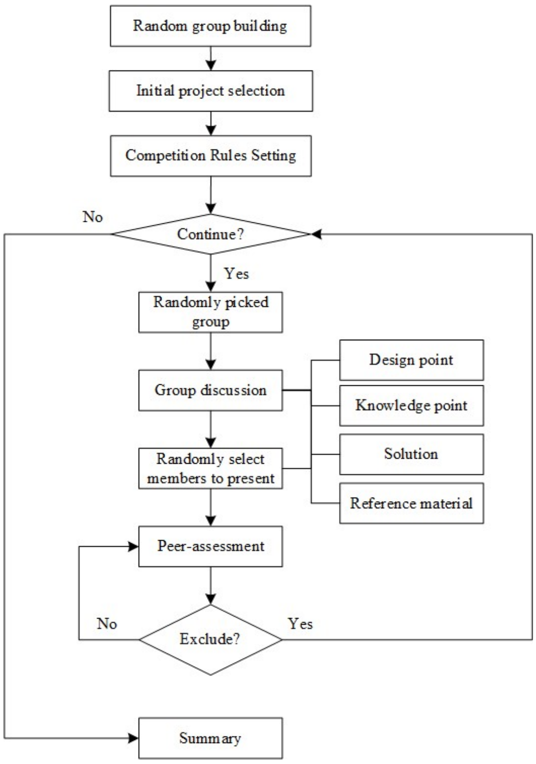

Fig. 3. Flipped project-based flipped classroom teaching flow chart.

IV. Teaching Effect Evaluation

A comparative experimental approach was utilized to substantiate the effectiveness of the flipped project-based flipped classroom model, as outlined in the aforementioned paper. The experiment took place during the spring semester of 2022–2023 and encompassed an experimental class along with two controlled classes, which adhered to the conventional course structure. The main sources of data employed in this study were computer experiments, midterm tests, and final exams. The quantitative analysis focuses on evaluating the impact of implementing flipped classrooms in large junior-level university classes.

A. Teaching Implementation

The implementation of the flipped project-based flipped classroom model was centered around the course titled "C Language Programming", specifically designed for first-year undergraduate students. In this experiment, this course had three distinct classes, each accommodating approximately 90 students. They are all engineering students and are approximately between the ages of 18 and 19. Following computer experiments and the mid-term examination, one class attained a ranking of third place out of a total of three classes, thereby earning the opportunity to adopt a flipped classroom approach. Consequently, with regards to instructional time, the implementation of the flipped classroom model was scheduled for the final theoretical class. The designated class is referred to as the experimental class, while the teaching methodology in the remaining two classes remained unaltered, denoted as the controlled class.

In the classroom, a collective of students was arranged into nine distinct groups, each comprising ten individuals. The initial project was called "Simple Calculator". The rules are as follows. The students are granted the opportunity to exercise autonomy in autonomously selecting their individual roles and responsibilities within their respective groups. In each iteration, the team that is selected at random is required to contribute a unique design element to the fundamental calculator project, ensuring that the proposed element has not been previously introduced. Every designed element should possess the corresponding grammatical knowledge points, solutions, relevant examples or exercises, and other pertinent material. Throughout the procedure, an elimination mechanism is employed whereby any group that fails to provide a distinct design point will be excluded.

The experiment was carried out over the course of three rounds inside three weeks, each round lasting one class hour in one week. Throughout all three rounds, each group actively contributed design points, with a cumulative representation of 27 individuals from their respective groups, who provided comprehensive explanations for the points formulated.

B. Teaching Interaction

Table I presents the results of the statistical analysis conducted on the various actions undertaken by students within the classroom during the course of this study. The majority of students actively participated in the group discussion as a member of the group during the exercise. According to the regulations governing the activity, it is stipulated that the repetition of design points is strictly prohibited, and any group found in violation of this rule will be disqualified. Consequently, in order to generate a distinctive and innovative design element, each group utilized search and query techniques, employing platforms such as courseware, OJ platform, internet, AI dialogue, and similar resources. In order to ensure equilibrium, each platform necessitated the involvement of merely two students, thereby yielding a cumulative participation rate of 80%. The event also incorporated a display link, wherein each display featured distinct student participants, resulting in a participation rate of up to 30%. During the mutual evaluation session, it is required that each group designate a student representative to provide their perspective. The level of engagement is about 30%. Table I illustrates that the establishment of activity rules fosters an environment that promotes and enhances student engagement.

TABLE I. List of Student Participation Activities

Order Number	Form of Participation	Participation
1	Group discussion	100%
2	Query	80%
3	Presentation	30%
4	Peer-assessment	30%

C. Performance

Table II presents the mean ranking of the eight daily computer tests, midterm examination scores, and final examination scores across the three classes. According to the data presented in Table II, the performance of the experimental class in regular and mid-term exams is deemed unsatisfactory, since it ranks lowest among the three courses. Nevertheless, there has been a significant enhancement in the overall performance of the experimental class in the final examination, resulting in their attainment of the highest position among the three classes. This implies that the implementation of flipped classrooms has had a significant and beneficial impact on students' ability to rebuild information and cultivate high-order thinking skills.

TABLE II. STATISTICS OF SCORE RANKING OF THREE CLASSES

Class	Average Computer Experiment	Midterm Exam	Final Exam
Experimental Class	3	3	**1**
Controlled Class 1	2	2	3
Controlled Class 2	**1**	**1**	2

The performance of three classes on five final exam problems is presented in Table III. The difficulty of the five questions increases in order from simple to difficult, and the important knowledge points of this semester are all designed in the questions. In this evaluation, there are five test data for each question to verify the correctness of the program. Each test data accounts for 20% of the score for this question. If all test data passes, the question will be considered full score. The design points pertaining to students in the flipped classroom were identified through the second, third, and fifth inquiries among the set of five questions. Based on the statistics, it can be observed that the experimental class exhibited superior performance compared to the other two classes in relation to these three specific problems. Despite the lack of direct relevance between the first and fourth questions and the flipped content covered in the flipped classroom, the performance of the experimental class is not ranked at the lowest level. Instead, it falls within the medium range because of the timeliness and scalability of the flipped classroom approach. This provides evidence for the effectiveness of flipped courses.

TABLE III. ACCURACIES OF FIVE PROBLEMS IN THE FINAL EXAM OF THREE CLASSES

Class	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
Experimental Class	95.12%	**78.05%**	**57.32%**	51.22%	**13.41%**
Controlled Class 1	94.05%	72.62%	53.57%	51.19%	8.33%
Controlled Class 2	**96.47%**	75.29%	56.47%	**52.94%**	5.88%

V. CONCLUSION

In order to effectively respond to the advancements in engineering capabilities and the evolving professional landscape, it is imperative to prioritize the cultivation of students' aptitude for integrating knowledge and engaging in high-order thinking processes. The proposed flipped project-based flipped classroom has been demonstrated that it has the potential to foster high-order thinking processes among students. The flipped project design is a novel methodology for teaching centered around student engagement. In forthcoming times, it is necessary to allocate greater consideration to the intricacies of the pedagogical process and projects to identify more suitable instructional materials for students.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Ning Fang conducted the research, analyzed the data, and wrote the paper; Junemng Cui curated the data and modified the paper format; both authors had approved the final version.

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