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A Teaching Ecosystem of Engineering Graphics Based on the Deeper Learning Cycle Model and Asynchronous SPOC

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Abstract. This study puts forward a solution to construct an Engineering Graphics teaching ecosystem consistent with the deep learning cycle model. The new system comprises a teaching environment including an asynchronous small private online course, "Mooclassroom" (a small program in Wechat for linking up MOOC-based and offline teaching), flip classroom, evaluation system, and the enterprise teaching mode and teaching atmosphere. Application of this ecosystem has proven that it effectively solves the problems of massive open online courses being difficult to adjust in time and of surface learning caused by viewing of electronic resources. It also makes connections between teaching content and enterprise demand. Thus, this ecosystem is beneficial to cultivate students' engineering and graphics-related thinking, innovative thinking, and critical thinking, as well as to improve their abilities of autonomous learning, engineering expression, and team cooperation. Simultaneously, it significantly improves students' final exam results.

Key Words: Teaching ecosystem, asynchronous SPOC, flip classroom, deeper learning cycle model.

MSC 2010: 97G80

1. Introduction

The natural ecosystem consists of the biological and non-biological environments (i.e., air, soil, water, etc.), while the teaching ecosystem consists of two parts — individuals (teachers and students) and the teaching environment (online teaching, classroom teaching, school facilities, social environment, etc.). The development of students is influenced by learning systems. Thus, this study aims to determine ways to build a teaching ecosystem that is more conducive to the development of students. So they can gain not only the knowledge and skills of autonomous deep learning but also the abilities to communicate effectively, perform teamwork, solve complex engineering drawing problems, and face challenges that require persistence.

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2. Current situation

The teaching environment is composed of a teaching site, teaching mode, and teaching atmosphere.

2.1. Teaching site

Because of the quality of their resources and learning processes, *massive open online courses* (MOOCs) have created a new learning experience for learners. However, learners find it difficult to enter a state of deeper learning in this environment due to monotony of the presentation mode, lack of targeted guidance, insufficient online participation, and inability to meet the individual learning needs of different groups [8].

The learning form of *small private online courses* (SPOCs), however, mainly includes self-regulated, cooperative, and inquiry learning. Thus, SPOCs make up for the inadequacy of MOOCs. Therefore, online learning has finally gone beyond the stage of copying classroom courses by innovating the classroom teaching mode, emphasizing a complete and deep learning experience for students, and enhancing students' motivation to learn, which are conducive to improving the completion rate of both the curriculum and course [12]. Therefore, SPOCs are more suitable as a teaching environment in the teaching ecosystem. This study adopted an asynchronous SPOC on "Modern Engineering Drawing" at the Dalian University of Technology, China, for analysis. More than 35000 students study on their MOOC every year, while about 570 students study on the SPOC of this study every year.

2.2. Teaching mode

From the perspective of students' learning, Bybee proposed the 4E learning cycle in [3]. On this basis, Eisenkraft presented a 7E learning cycle model in the form of elicit, engage, explore, explain, elaborate, evaluate, and extend [5]. Sarac found that the learning cycle model has a positive impact on students' performance through meta-analysis [11]. Ozmen confirmed that the implementation of the constructivism method in the educational process is achieved through the learning cycle model [10].

From the perspective of teachers' teaching, in 1976 Marton et al. [7] put forward two relative concepts of deep learning and surface learning. Based on this concept, Biggs [1] conducted a comparative study of deep learning and surface learning from the perspectives of knowledge system, initiative, state of reflection, migration ability, thinking level, etc.. Jensen et al. [6] proposed the deeper learning cycle that consists of seven steps: design standards and courses, conduct pre-assessment, create a positive learning culture, prepare and activate prior knowledge, acquire new knowledge, deeply process the knowledge, and evaluate students' learning. Bransford believes that deep learning requires a student-centered constructive teaching environment, a knowledge-centered contextual teaching environment, an evaluation-centered reflective teaching environment, and a community-centered social environment [2].

Drawing on and combining the 7E learning cycle and deep learning cycle, this study's deep learning process model of the teaching ecosystem involves guiding and preparing, participating and reflecting, exploring and constructing, applying and expanding, evaluating and reflecting, and communicating and interacting. The aim is to promote understanding, construction, migration, application, problem solving, reflection, and other abilities to train students to achieve deep learning, develop applications, and conduct analysis, synthesis, and evaluation through higher-level thinking.

2.3. Teaching atmosphere

The growing empirical research shows that students' command of academic skills and content certainly matters, but so does their ability to communicate effectively, work well in teams, solve complex problems, persist in the face of challenges, and monitor and direct their own learning — that is, the various types of knowledge and skills grouped together under the banner of "deeper learning" [4].

A good interactive learning atmosphere is the foundation and support of deeper learning. A collaborative learning environment promotes problem solving and thus knowledge construction, ultimately helping learners to achieve deeper learning. Mingxing proposed to design an interactive teaching process, build interactive teaching content and environment, use interactive communication tools, and cultivate interactive learning subject to improve the degree of interaction among people and between people and the environment. The interactive design of the teaching system is carried out in the evaluation, and an ecologically intelligent learning situation is formed to improve the interaction of the system [9].

In sum, the teaching site, teaching mode, and teaching atmosphere should be integrated organically into the teaching ecosystem.

3. Engineering Graphics teaching ecosystem based on the deep learning cycle model

Factors that affect the operation of a teaching ecosystem include the following: First, the teaching hardware system is composed of the teaching environment and teaching mode. Second, the teaching software system is created by the interaction between teachers and students, among students, teaching assistant and student, and between teachers and students and enterprises. The structure of the teaching ecosystem is shown in Figure 1.

3.1. Teaching environment in the teaching ecosystem

3.1.1. Guidance and preparation (elicit and reflect)

The *elicit* is the first and most important link in the whole teaching process. The purpose of elicit is to introduce teaching objectives and determine which problems are going to be solved and why. Throughout the Engineering Graphics course, "elicit" is conducted once a week.

In this study, the students addressed are freshmen. There are 84 hours each year that needs 28 weeks in 2 semesters to complete the teaching. The student-faculty ratio is 1:132. There are about 66 students in each class.

Prior to the course, the teacher makes the whole semester's teaching plan and one week's teaching design (including the design of a matching flip class) according to the student's situation. Then, the teacher releases cloned MOOC content and develops the school's asynchronous SPOC's online teaching resources, including the MOOC's supplementary cases, micro-video, homework commentary, discussion topics, and other materials. Next, the teacher sets clear scoring standards, assignments, and test submission deadlines. At the same time, the teacher analyzes online data to understand the problems and difficulties students encounter online. It should be emphasized that the flip classroom also needs further guidance, discussion of cases to lead to key content, introduction of learning methods, and creation of a good positive learning atmosphere.

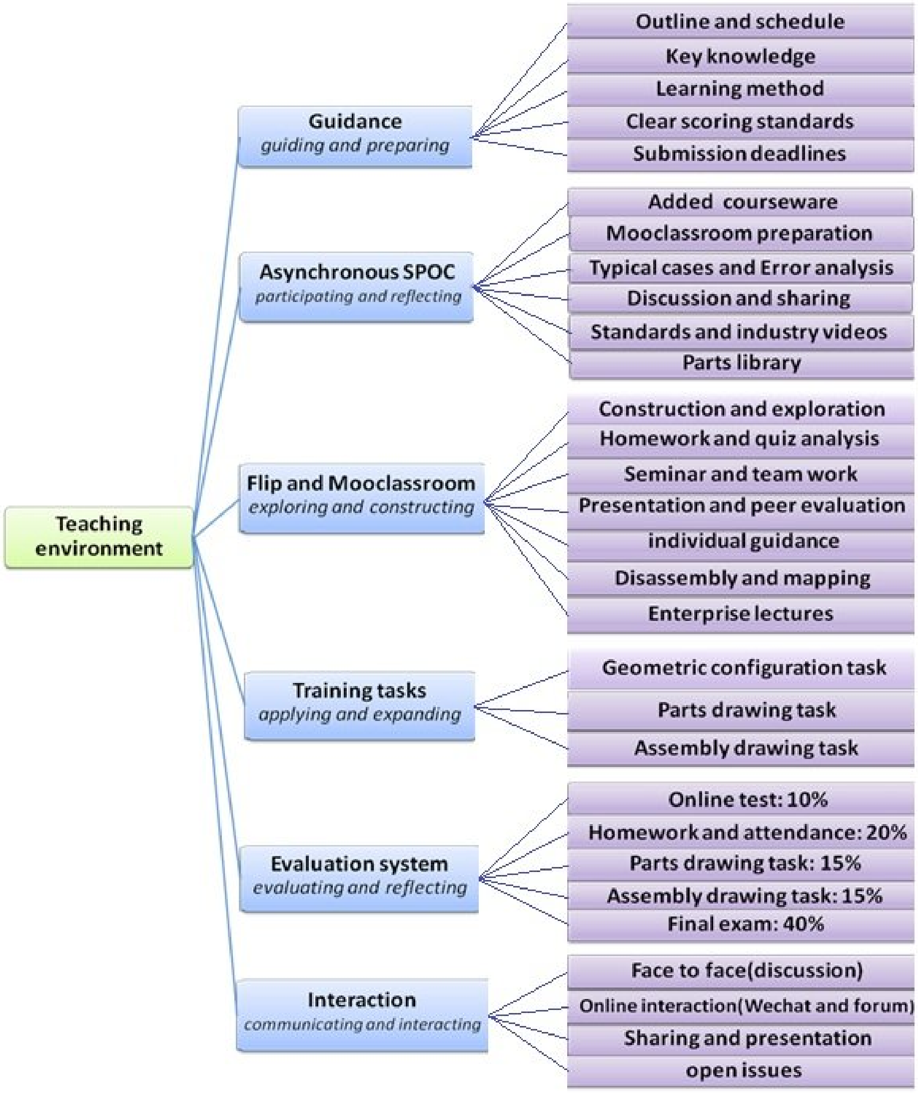

Figure 1: Structure of the teaching ecosystem.

3.1.2. Asynchronous SPOC (engage and first reflection)

How to attract students to participate and maintain their enthusiasm for learning is a problem that all online courses face. Timely feedback on students' issues in the discussion area is important for teachers and teaching assistants.

By analyzing online data, teachers appropriately transform the MOOC content according to the needs of students by designing circumstances of micro-video or gamification micro-courseware, preparing the "Mooclassroom" (a small program for assisting teaching), through classroom tests and questionnaires, adding typical case questions, conducting assignment error analysis, ensuring enterprise-related standards, adhering to the mechanical product design process, drawing expression methods, providing engineering site micro-video and interview video, etc.. Thus, students can understand the design, production, assembly, testing, and construction processes. Moreover, teachers arrange opening problem assignments such as related to data collection, sharing, and discussion to stimulate students' enthusiasm for participation. The activities of SPOC are shown in Figure 2.

Figure 2: The activities of SPOC.

3.1.3. Flipped classroom (exploration and construction)

A flipped classroom takes on several main roles. The first involves exploration and construction in the specific circumstances of students, the second involves instant feedback and reflection, the third involves expression and consultation, and the fourth involves cultivation of critical thinking. A flipped classroom usually involves example analysis, groups for exploratory and constructive teaching content, component disassembly and mapping, student achievement display, peer evaluation, and other content.

In this classroom, most importantly, teachers need to design exploration activities, discuss problems, construct training, and develop test questions and questionnaires in the "Mooclassroom". They also need to give students individual guidance in the classroom, encourage them to ask questions and express ideas, guide them to integrate information to build knowledge points of the curriculum and apply knowledge principles to explain problems and phenomena, and train them in the application of their analytical ability and team skills. The activities of flipped classroom are shown in Figure 3.

3.1.4. Group project training (elaboration and extension)

The ultimate goal of deep learning is to solve complex real problems. Group projects provide close to the real application scenarios of knowledge, including the following: complex three-dimensional innovative configuration training, part drawing project training, and assembly drawing project training. There is a progressive association between the three types of training. Each type of training lays the foundation for a follow-up training.

The complex three-dimensional innovative configuration training carried out by an inventor software is an open topic that aims to combine the application of constructive thinking and skills, stimulate students' interest in learning, and cultivate their innovative motivation

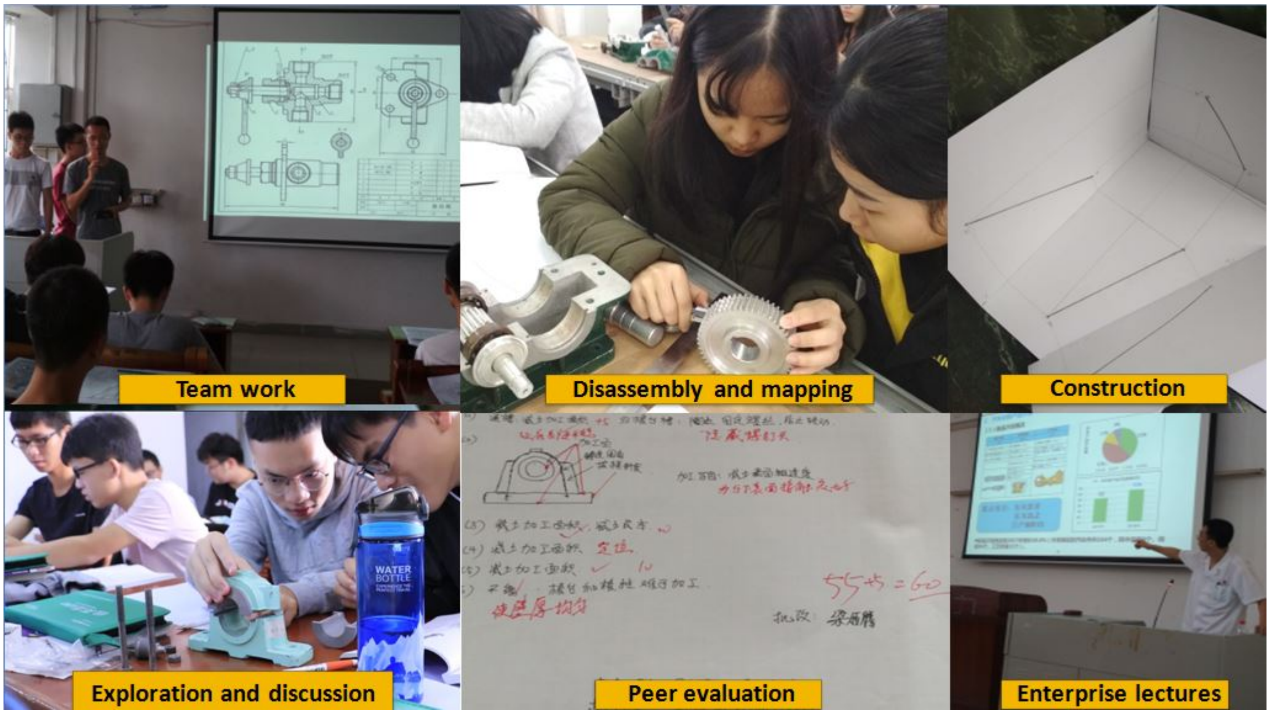

Figure 3: The activities of flipped classroom.

and innovation ability.

The part drawing project training emphasizes engineering norms, cultivates students' engineering awareness and transfer of comprehensive expression skills, and makes them advance and use freely their expressions of engineering drawings through the feedback, reflection, modification, and feedback loop of problems that arise in the project.

At the end of the course, the training arrangement of the assembly drawing project can be combined to train the students to help them gain the abilities of transfer, coordination, cooperation, display of expression, and critical reflection. The training topic is chosen by students semi-autonomously through free combination of the grouping method, which makes clear the requirements for cooperation and has detailed cooperation scoring criteria. The process of writing the project report involves profound reflection, and most students can sum up their own acquisition and problems. Thus, students' meta-cognitive levels can be improved.

3.1.5. Evaluation

The evaluation system is a combination of process and result evaluation as well as of online and offline evaluation. The overall evaluation method is shown in Figure 4. Online evaluation includes asynchronous SPOC online automatic evaluation and asynchronous SPOC online peer evaluation. Offline evaluation includes a flip classroom seminar and training peer evaluation, project training group display evaluation, midterm testing, and the final test.

Peer evaluation of seminars and assignments prompts students to comprehensively invoke their knowledge inventory as well as contrast, criticize, and reflect from the perspective of the examination. When the project training team presents, the audience can question the presenter about the project's expression and structure. Through the iteration cycle of self-reflection and critical thinking, the students' meta-cognitive level can be improved. This

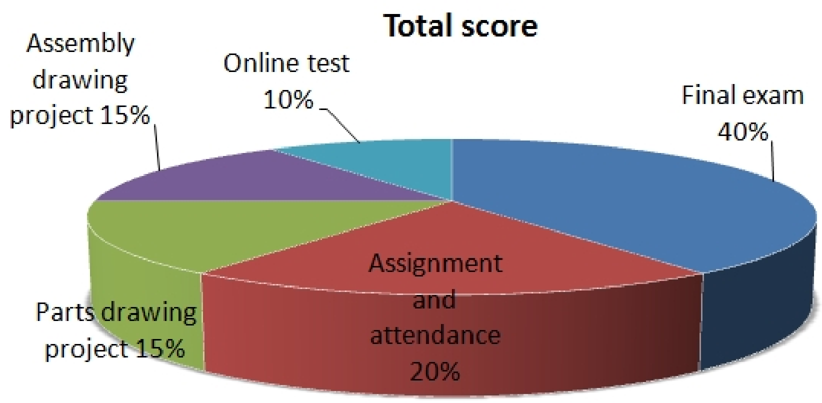

Figure 4: The evaluation system.

promotes deeper learning.

3.2. Communication and interaction in the teaching ecosystem

It is suggested that students' brain cells must be provided with a safe environment to ensure that they are in a growth mode. The feeling of security allows the brain to allocate resources for complex understanding. This is critical because our emotions and perceptions are related to each other [6]. Human cognitive phenomena include not only the cognitive activity that occurs in the individual's mind but also the process of interaction between people and between humans and technical tools to conduct an activity.

This study distributed online questionnaires for 280 students to ask them whether they liked taking the discussion class and their expectations of their final grades. The responses were analyzed using achi-square test and contingency tables, to observe the correlation between a single argument and the dependent variable. The results are shown in Figure 5.

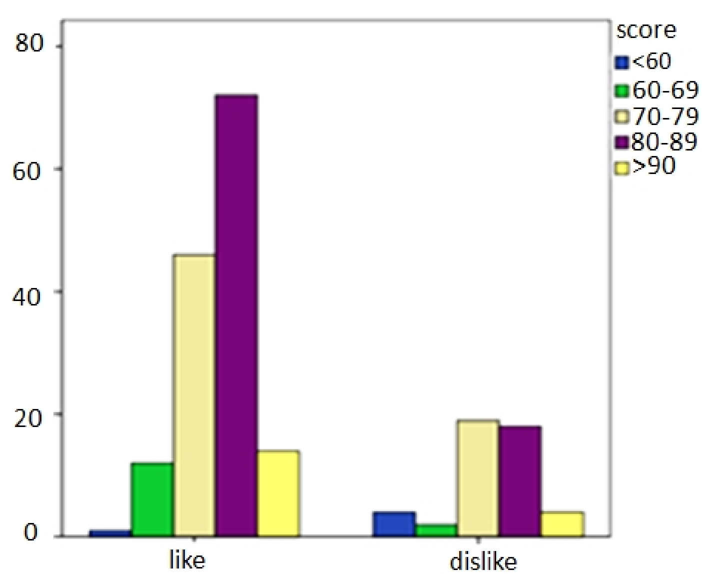

Figure 5: Questionnaire result.

Figure 5 shows that students who prefer group discussions achieve higher grades (80–89 and above) than those who do not like group discussions. Questionnaires indicated that interaction during teaching promotes deep learning. Communication and interaction have a positive effect on students' learning effect and learning experience. During teaching, students should be encouraged and stimulated to express their ideas, criticize actively, and reflect.

3.2.1. Types of interactions

The interactions between teachers and students, students and students, and teachers and students and enterprises play a vital role in the operation of the teaching ecosystem.

There are two ways to conduct such interactions online: WeChat group and forum. A WeChat group is usually a small group of classes that has the advantages of fast feedback, convenience of sending pictures and files, and communication through voice or small video. The MOOC forum's advantages are that it can communicate with students and teachers throughout the country and even the world, and they can in turn learn from and motivate each other. Students interact with engineers by the Wechat forum to

expand their horizons,

cultivate engineering awareness,

conduct corporate lectures and seminars,

understand the changes in product development, design processes, and production methods through expert lectures and business cases,

understand the drawing specifications of different countries, and

understand the enterprise quality assurance system.

It is important to note that the content of the lecture should be suitable for the current situation of students' professional knowledge to have a better effect.

3.2.2. Method of promoting interaction

Similar to the role of the air in our environment, good communication and interaction seep into every aspect of the teaching environment and need to be monitored and mediated at any time to ensure that students' learning atmosphere is safe, positive, and enjoyable.

Teachers should create an atmosphere conducive to discussion in teaching — an effective way to design hierarchical discussion questions — questioning themselves, triggering further student discussion, designing open issues, leading by example to guide students to break the blind obedience to tradition and authority, and inspiring them to question others' views.

4. Teaching efficiency

After completing two semesters of MOOC and one semester of SPOC teaching, positive teaching results have been obtained. MOOC and SPOC students have significantly improved their ability to solve problems with application of knowledge than traditional classroom students have, with the top 60% of students who won the school's annual Engineering Drawing and CAD Competition being MOOC and SPOC-style students. According to questionnaire survey, 88.02% of students are willing to choose online and offline hybrid teaching in subsequent courses. Moreover, 91.7% of students would like to recommend the current teaching model to their junior fellow apprentice.

5. Conclusions

For teachers, it is a challenge to consider and design all aspects of a course that will affect students' learning and ability.

Teaching results of two semesters of MOOC and one semester of SPOC demonstrate that a teaching ecosystem based on the deeper learning cycle model and asynchronous SPOC considers the construction of not only the teaching mode and teaching environment but also a good interactive atmosphere between teachers and students. It not only effectively utilizes the excellent resources of MOOCs but also overcomes the problems caused by large-scale MOOCs. Thus, this ecosystem is conducive to guiding students' deeper learning.

With the aim of cultivating students' structured, innovative, and critical thinking as well as improving their abilities of self-regulated learning, engineering expression, teamwork, and solving of complex graphics problems, the achievement of students' Engineering Drawing courses has improved significantly by the use of our proposed teaching ecosystem.

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