Research on the Integration of Maker Education and University Curriculum

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Abstract. Maker education is a new form of education based on the maker movement and maker spirit. The core of it is learning from creation. In the traditional sense, conducting maker education usually requires material support from "maker space" and "open-source" platforms. its content is mainly limited to the fields of industrial design and manufacturing. This underestimates the application value and scope of maker education. Based on a comprehensive analysis of its connotations and characteristics, we propose the idea of integrating maker education with the university curriculum and designing a teaching model. After that, we validated the feasibility of the model through a teaching experiment.

Keywords: Maker movement; Makers; Maker education; Curriculum; Teaching experiment.

1 Introduction

In the past decade, with the rapid development of open-source hardware such as 3D printing, laser cutting, CNC machines, etc., individual creators have become a significant force that cannot be underestimated in the fields of technological innovation and industrial manufacturing. The maker movement has subsequently swept the entire world.

2 Maker movement and makers

The main content of the maker movement involves a growing number of people using do-it-yourself (DIY) and do-it-with-others (DIWO) techniques and processes to create unique technology products. This movement also includes innovations and inventions that have never existed before, created by individuals in their homes, garages, or other places with limited manufacturing resources.[1] In the book "Makers: The New Industrial Revolution," the author Chris Anderson makes the point that the maker movement has three transformative commonalities: (1) People use digital desktop tools to design new products and create model samples ("Digital DIY"); (2) Sharing design achievements and collaborating in open-source communities has become a cultural norm; (3) If willing, everyone can transfer a design compliant with generic design document standards to a commercial manufacturing service provider and have it produced in any quantity and scale. They can also produce it using desktop tools by themselves.[2]

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The maker movement can be seen as a shift in manufacturing methods and technological innovation, enabling more personalized and decentralized design and production processes.

Consequently, individuals who participate in the maker movement are referred to as makers. They can be considered as individuals who are obsessed with new technologies and passionate about creating, designing, and manufacturing in DIY or DIWO ways. They are willing to share their knowledge with others whenever and wherever possible.

"User innovation" is the primary idea, and using new technologies, open-source hardware and self-made tools are the distinguishing features of them. It is a typical embodiment of the innovation 2.0 model for the knowledge society in the field of design and manufacturing.

3 Maker education

When the maker movement intersects with education, "maker education" emerges. It represents a new, specific type of educational approach with teaching and learning activities, methods, and tools that are deeply influenced by the maker movement. The core of it is "learning from creation".

Some experts in this field, such as Zhu Zhiting, believe that maker education originated from John Dewey's "learning by doing" theory and is highly compatible with experiential education.[3] Yang Xiaozhe emphasized that maker education should include several key behaviors, such as the use of digital tools, practical learning, and work creation.[4] Zhao Chengling pointed out that maker education has the characteristics of interdisciplinary learning and the integration of O2O (Online To Offline) time and space. He also emphasized the important role of collaboration in the learning process.[5] Huang Zhaoxin and his research partners further proposed that maker education is an optimization and expansion of STEAM education. It can provide engineering materials and teaching media for STEAM education.[6]

Based on the above viewpoints, we can develop a comprehensive understanding of maker education. From a theoretical perspective, we will find that maker education is a new learning style that involves a set of learning methods and steps based on creation activities. It represents the latest form and evolution of John Dewey's "learning by doing" educational philosophy in today's technological landscape. From a technological perspective, we can consider maker education as a multi-dimensional composite process that integrates offline-to-online (O2O) space and various educational resources. It makes full use of open-source platforms (hardware/software) to implement learning plans. From a management perspective, we may find that project-based learning (PBL) is the fundamental unit of maker education. From a disciplinary perspective, maker education generally involves a foundation in large-scale engineering, technological expertise, and interdisciplinary approaches.

4 Maker education and curriculum

In most universities or primary and secondary schools, maker education is implemented in various activity classes or clubs, depending on different material conditions. The benefits obtained in this way are quite limited, so scholars advocate for its integration into regular curriculum and ordinary classrooms.[7]

Accordingly, thorough course reforms must be carried out as follows:

Firstly, course contents should be rewritten to align with the requirements of PBL, and the traditional linear teaching sequence should be restructured into a modular format. At the same time, it is necessary to design a series of projects with practical value and a certain level of difficulty to enhance students' learning experience.

Secondly, comprehensive reforms should be implemented regarding methods, tools, schedules, and facilities. For example, the teacher-led theory lecturing, demonstrations, and case studies can be transformed into student-centered learning approaches such as exploratory learning, activity-based learning, experiential learning, and collaborative learning. The teaching schedule should not be limited to a few fixed time periods on the timetable but should be placed within a broader and more flexible time framework. This approach allows students to engage in personalized adaptive learning. The tools and environment for learning should be based on digitization and networking, enabling online learning and testing, virtual simulation practices, and utilizing various open-source digital tools to play a more significant role in the learning process. Teaching and learning facilities are not limited to classrooms or laboratories but can be expanded to more practical production places such as maker spaces, open laboratories, and workshops, among others.

Thirdly, the process of teaching and learning a course needs to be rebuilt. Various activities in class and after class, based on modular contents and corresponding practical projects, need to be carefully designed and implemented. Subsequently, the contents of these activities and projects combine to form a complete curriculum.

Fourthly, after the modular transformation, the course evaluation mechanism must be reformed as well. Multiple evaluation methods should be adopted simultaneously.

5 A model Integrating maker education and course teaching

Based on the analysis above, we have formulated a model that integrates maker education with course teaching.

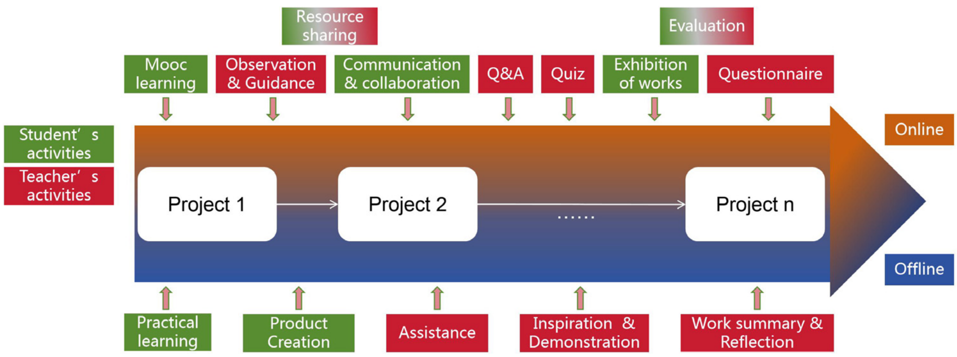

Fig. 1. Model integrating maker education and course teaching.

As shown in Figure 1, a course can be redesigned and divided into a series of projects with derivative learning and creation activities distributed in both online and offline environments. A giant arrow is used to represent the continuum of space and time that encompasses the progression of all project activities. It points in the right direction by illustrating the linear characteristics of a course schedule, but this does not imply that the implementation of each project must adhere to a specific sequence. They can be completely independent and carried out in any order according to needs. The upper and lower parts of the arrow are in two colors blending together. It represents the integration of the entire online and offline space.

Fourteen types of activities conducted by the teacher and students to accomplish the projects are summarized. Above the arrow represent online activities, while below represent offline activities.

Different colors are used to distinguish activities led by students or the teacher, respectively. The green markers belong to the students, while the red markers are primarily used by the teacher. The alternating red and green cells indicate that both the teacher and students need to complete those tasks.

Specifically, we can see that the students' online activities include MOOC learning, resource sharing, communication & collaboration, exhibition of works, evaluation. The online activities led by the teacher include resource sharing, observation & guidance, Q&A, quizzes, questionnaires, and evaluation.

"Resource sharing" and "evaluation" are two types of activities performed by both the teacher and students. The reasons are as follows: the resources shared by the teacher for students must have a more explicit object orientation, which can help students avoid detours and improve their efficiency, and the resources that students independently explore and share with each other may be more diverse and divergent. Encourage students to participate in the evaluation process by utilizing various assessment methods, including teacher evaluation, group evaluation, intergroup evaluation, peer evaluation among students, and self-evaluation. This can expand the scope of course evaluation to gather more comprehensive and objective data and draw conclusions. At the same time, it can also stimulate students' competitive spirit and sense of achievement, promoting learning.

The offline activities of students include "practical learning" and "product creation," which are often accomplished synchronously. The reason for distinguishing them is that they focus on different phases of learning and need to be evaluated in different ways. Practical learning emphasizes the intermediate process, so it calls for process evaluation methods. Product creation emphasizes the outcome, so methods for evaluating results are more suitable.

The teacher's offline activities include providing "assistance", "inspiration & demonstration", "work summary & reflection" for students.

Compared to general maker activities or behaviors that necessitate setting up a dedicated "maker space" offline beforehand, these distributed learning and creation activities in the hybrid digital environment are more convenient and cost-effective. Students will be more proactive in their learning, and the connection between the teacher and the students will be more diverse, frequent, and prompt.

6 A teaching experiment on the model

To verify the feasibility of the model proposed above, we conducted a teaching experiment. The main processes were as follows:

Firstly, we have selected the course "Business Photography" as the experimental subject. Although the main objectives of this course did not focus on physical product design and development, as is typical of maker behaviors. It requires high practical, collaborative, and creative abilities from students, which is very consistent with the concept of maker education. The content is also suitable for breaking down into modules for project-based learning. Additionally, photographic works are a type of creative production that is highly suitable for online sharing and evaluation.

Then, we conducted a parallel-group teaching experiment. Two natural classes were designated as control and experimental groups.

For the control group, we conducted routine teaching using offline face-to-face lectures and demonstrations in classroom and laboratory settings separately.

For the experimental group, we implemented the new model and conducted Project-Based Learning (PBL) with various activities outlined in Figure 1 within a blended learning environment that combined online and offline components.

An online course has been established on the Chaoxing MOOC Platform that includes all the theoretical content of the "Business Photography" course and the learning resources selected by the teacher. It also provided digital tools and spaces for the teacher and students to engage in various online activities.

Six projects were well-designed, covering all the contents and objectives of the course. Students were required to submit photographic works representing their achievements for evaluation.

The offline learning and creation activities of the experimental group were conducted in a fully equipped photo studio designed like a workshop. All equipment and tools are readily available throughout the course.

For the purpose of comparing learning achievements between the two groups, six tasks were assigned to the control group, which had nearly identical requirements to the projects of the experimental group. Students in the control group were also required to submit photographic works for evaluation of the results.

According to the course outline, an evaluation plan based on work evaluation was proposed. A two-level quantitative criteria, including 3 primary indicators and 12 secondary indicators, has been designed accordingly. The three primary indicators include "Technicality", "Artistry", and "Creation", while the twelve secondary indicators include "Focus", "Exposure", "Sharpness", "Perspective Effect", "Depth of Field Control", "Color Expression", "Composition", "Lighting and Modeling", "Content Creation", and "Ideological Expression".

Referring to the same scoring criteria, we evaluated all the photographic works of both the experimental group and the control group. By comparison, we found that the overall achievements of the experimental group were significantly higher than those of the control group. The average scores for each project were 3-8 points higher in the experimental group. For the highest score, there was no significant difference between the experimental group and the control group, but low scores were generally found in the control group. From the distribution of scores, it can be seen that the quality of works produced by the experimental group was relatively stable, and the score range tended to be concentrated. However, the quality of works produced by the control group was uneven, with a large degree of dispersion in scores.

According to these findings, we can roughly infer that the new model has a more stable and improved learning outcome. Although it may not have an immediate effect on some excellent or weak students, it can still benefit most students.

Considering that work evaluations do not directly measure and provide feedback on learning outcomes in an objective and quantitative manner, and there may be subjectivity from evaluators (teachers or students) involved in the process. As a supplementary study, we designed a questionnaire to assess self-evaluation of learning achievement and distributed it to both the experimental group and the control group. All students in both groups were asked to complete the task independently. In the questionnaire, we included a 5-level Likert scale with 20 questions, each corresponding to a main objective and content specified in the course outline. Students made independent judgments and assigned 5 points to those who believed they had a very good grasp, 4 points to those who were good, 3 points to those who were average, 2 points to those who were poor, and 1 point to those who were very poor.

Due to the large volume of sample data, we calculated the average self-evaluation scores of students in both the experimental and control groups for each question to facilitate a more intuitive comparison. Then, two lines were used to connect these average scores.

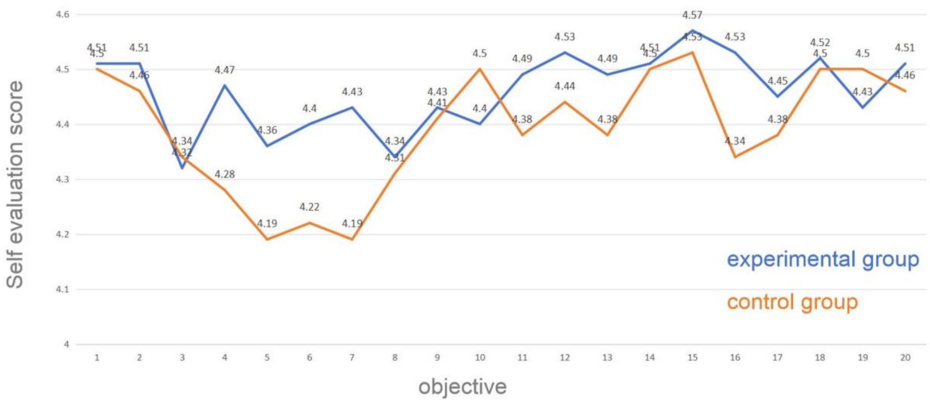

Fig. 2. Self evaluation of achievement on course learning objectives.

As shown in Figure 2, the blue line represents the average scores of students in the experimental group for each question, while the orange line represents the average scores of the control group.

We can clearly see that students in the experimental group generally believe that they have a good grasp of the learning content and a high degree of objective achievement, while students in the control group believe that their mastery level is relatively low.

Subsequently, we conducted another questionnaire for an additional survey and distributed it separately to the experimental group. We wanted to determine whether students in the experiment have a positive or negative attitude towards this new teaching model based on their subjective attitudes. Therefore, we designed a new 5-level Likert scale in the questionnaire to gather relevant information.

Starting from the three dimensions of "attitude" defined in psychology (cognition, emotion, and behavioral intention), we have prepared 12 questions in advance. On the basis of soliciting the opinions of two professors in their respective fields to evaluate the appropriateness of the questions, five undergraduate students were also selected to test the readability of the questionnaire. Finally, we revised 8 questions, which are listed in Table 1.

Table 1. Attitude self-test results for the model.

Question	Average score
I think the new model is effective.	4.688
I am willing to participate online activities.	4.733
I am willing to participate offline activities.	4.8
I am adapted to project-based learning.	4.755
I often get motivation and help during the course.	4.755
I always stay focused during the course.	4.511
I always enjoy sharing and collaborating with others.	4.422
I will actively seek solutions to problems.	4.466

Then, we conducted a formal investigation. we distributed and collected 45 valid questionnaires in the experimental group. Through internal consistency reliability analysis of the questionnaire, with sample N=45, its Cronbach. a is 0.918, indicating good reliability.

From Table 1, we can also see the average score for each question given by all 45 students in the experimental group. (5 points is the highest score, 1 point is the lowest score).

The average total score given by all 45 students for the 8 questions is 37.13 points. If the full score of 40 points is converted to a percentage system, the average score on the scale is 92.825. It can be inferred that most of the students are quite positive about the new model. It also proves that our teaching reform is effective beyond the perspective of academic scores.

7 Conclusions

The development of society and the advancement of technology have driven the transformation of technological innovation models. The traditional technological innovation activities guided by technological development, with researchers as the main body and laboratories as the carrier, are gradually shifting towards the Innovation 2.0 model, which is user-centered, with social practice scenarios as the stage, and characterized by collaborative innovation and open innovation. In this process, education should also incorporate the cultivation of people's innovative abilities into its target scope and assume corresponding functions.

Through this research on the integration of maker education and course teaching, we have found that the key to cultivating student creativity lies in stimulating their internal learning motivation, sense of achievement, and competitive awareness. It is also necessary to guide them to actively think and participate in practice, connect learning with life and work, and further provide external driving forces. Therefore, it is necessary for teachers to continuously optimize teaching methods, means, tools, and processes, constantly think and try new teaching models, and conduct theoretical research and practical exploration. This is also a lifelong career that a teacher should devote themselves to.

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