To improve learning effect in mechanical component design by 3D printing—Assistive device design as an example

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Abstract

The aim of mechanical component design, one of the core courses in mechanical engineering, is to teach students how to design products with both functionality and safety. This is a complex but challenging course including mechanical drawing, statics, dynamics, mechanics, and material mechanics. Due to the rapid advance in computer technology, currently utilization of computer aided technology in mechanical computer design can help students to show the product information quickly by virtual 3D design.In this study, the difference in learning effect with or without utilization of 3D printing technology in mechanical component design will be evaluated. Originally the product design is completed by class teaching, memory of students, and computer aided drawing. In this case, the learning effect of students is influenced by personal knowledge and experience, spatial difference, virtual-real situational change barrier. In order to overcome these negative effects, a series of guided courses to design small-sized assistive devices will be planned. By utilization of 3D printing technology, the spatial difference and virtual-real situational change barrier will be abolished. During the course, students initially make 3D drawings, and then adjust the size of components by 3D printing to create the final product. In the end, the learning effect will be determined by the scores of final products and the questionnaire of students.

Key words: 3D Printing, Mechanical Component Design, Assistive Device Design, Questionnaire

Introduction

The mechanical component design course is a key course for teaching mechanical engineering students to have the ability to design components. The learning outcome of the course is to evaluate whether students will be able to serve as mechanical design engineers in the future. Mechanical design is widely used in daily life, and it can be applied to items of moving objects, such as vehicles, alarm clocks, blenders, and air-conditioners. The main goal of this course is to teach students to design functional mechanical components with high safety. However, this is not an easy task. Mechanical drawing, statics, dynamics, mechanics, material mechanics, and computer aided design should be learned before taking this course. According to the current teaching results, students have the problems of "insufficient creativity" and "virtual and real situational transition barriers" in the component design process. Insufficient creativity can be improved by using extra creative thinking tools during the course; the barriers of virtual and actual situations can be overcome by manufacturing real objects. Due to the limitation of time and cost, 3D printing technology is a good tool to overcome these drawbacks.

In 2013, 3D printers were introduced into 21 schools and then used for teaching in a pilot plan. According to the feedback reports from most schools, the 3D printing machine, as a teaching resource, had the potential to increase students' learning motivation and enhance the promotion of science, technology, engineering, and mathematics (STEM) subjects [1]. Makino et al. created a public digital manufacturing space "Eki-Fab" for students of junior and senior high schools to explore and recognize features of 3D printing technology in digital manufacturing. For university students, problem based learning (PBL) was used to learn the relationship between 3D printers and modeling techniques [2]. Makino et al. suggested that 3D printing could be used in the STEM education. They had used the whistle as an example. The difference in the frequency of the blown sound was studied by changing the geometric dimensions of the whistle by CAD drawing and then producing whistles accordingly by 3D printing [3].

Bull et al. found that 3D printing technology enabled kits designed and manufactured in engineering field to be used to improve learning efficiency through relevant experiments [4]. Hamidi et al. used a series of hands-on collaborative group learning activities for the design and implementation by using robotics, 3D modeling, and 3D printing, allowing students to better understand electromechanical engineering and computer science education [5]. Togou et al. implemented the EU Horizon 2020 NEWTON project and constructed the NEWTON Fab Lab STEM with the goal of assessing the impact of using 3D printing as a support tool to increase student interest in STEM subjects. In the end, 83% of students favored to integrate 3D printing courses into science education [6]. Buehler et al. explored several special features of utilizing 3D printing technology in STEM engagement, educational aids for accessibility content creation, and the possibility of creating custom adaptive devices. According to the results, therapists, educators, and administrators who wished to implement them all could use these design tools in special educational environments [7].

Buehler et al. found that students, teachers, and nursing staffs benefited from the introduction of 3D printing into the special education. It contained three locations serving populations with varying ability, including individuals with cognitive, motor, and visual impairments [8]. Audette et al. evaluated the feedback of national navies in using 3D printing technology in the ONR-funded project. The navy used 3D printing for reverse engineering to improve the skills of members in computer-aided design, additive manufacturing, product life cycle management, and component retrieval. This process also promoted the STEM knowledge and professional development and allowed the crew to solve problems through creative design methods [9]. Verner and Merksamer evaluated the process of using 3D printers in educational programs by school teachers to increase the knowledge and skills of students in digital design and manufacturing. Based on the results, conceive-design-implement-operate (CDIO) approach could be used to balance between learning instructional foundations, training technical skills, and teaching practices. This study also showed that learning activities in the curriculum helped to develop visual literacy skills [10]. Garcia et al. explored the application of 3D printing technology in health education. Anatomically, the surgeon completed 3D printing instruction by creating geometry, optimizing printing parameters, and selecting the appropriate 3D printing machine and materials. This process could significantly improve the knowledge and skills of the students in the new generation of surgeons in the patient-specific models with anatomical fidelity created from imaging dataset [11].The purpose of this study is to evaluate if creative teaching courses and 3D printing technology, using small assistive device design as an example, can improve the "insufficient creativity" and "virtual and real situational transition barriers". In this case, the discrepancy between the course and the reality can be reduced by applying the product design which really happens in the real world into the course.

Material and Method

The implementation of this research includes courses for mechanical component design, confirmation of design requirements, previous patent searching, and group discussion. Questionnaires are given before and after the course to confirm the effectiveness of the study. The flowchart of this study is shown in Figure 1. The details of the course are described in the following sections.

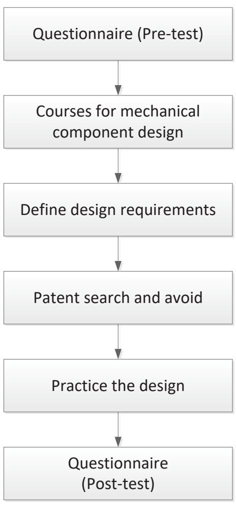

Fig. 1 The flowchart of this study

A. Courses for mechanical component design

The goal of the course is to teach the safety and functionality of the components. The safety course includes different forms of loading design, main analysis of the force mode, damage generation, and fatigue life of the components. The functionality course includes the dimensional geometry design and destruction mode in terms of tolerances, keys, couplings, and gears.

B. Define design requirements

The goal of the course is to develop small-sized accessories. Many points are needed to be considered in the development process of the accessory, from the observation of clinical needs to the definition of customer needs. In order to allow students to more clearly target and define requirements, an analytical tool "mind map" is used. Mind maps visualize the construction and classification based on a central keyword or idea, which radiantly connects all other graphical representations of words, ideas, tasks, or other related projects [12]. Different ways can be used to express people's ideas, such as quotation, visible visualization, construction of system, and classification. It is commonly applied in research, organization, problem solving, and policy development [13].

C. Patent search and avoid

By the aid of the mind map, the appearance of the product under development can be clearly defined. It is necessary to produce a product that is more novel, advanced, and even functional. In order to correctly distinguish the difference between the new design and the commercially available product, the retrieval and comparison with the previous patent cases are needed. During the comparison, possible technological breakthroughs are anticipated. After the reinforce of the structure and system functions, applying for invention patents is possible. For the search of the patent case, searching in the websites of google and the intellectual property office moea R. O.C. is performed.

D. Practice the design

The group discussion is necessary for PBL. Each group consists of 4-5 students. One person is appointed as the team leader, responsible for communication with the instructor and the teaching assistant. Another one is the recorder, responsible for recording the whole development process of the group and supervising the progress of other members. Team members need to follow the time schedule, search for data, discuss, draw 3D drawings of the designed product, and complete 3D printing of this product.

E. Questionnaire

The learning outcomes of students are confirmed through questionnaires, which will be performed before and after the course. Then the pre-course and after-course questionnaires will be analyzed. In the questionnaire, there are 23 questions, which score 1-5 respectively (1 is very disagree, 2 is disagree, 3 is neutral, 4 is agree and 5 is completely agree). The questions are divided into four parts, including "learning content and skills", "team engagement level", "task achievement" and "course summary". The contents of the questionnaire are shown in Tables 1 to 4.

TABLE I

LEARNING CONTENT AND SKILLS

Q 1	I understand the basic concepts and curriculum design of this teaching.
Q 2	This teaching method can improve my understanding of the course content and knowledge of the subject area.
Q 3	This teaching method can help me link the knowledge of the subject area with the knowledge I have learned before.
Q 4	Through this teaching method, in the process of solving problems, I can encourage myself to actively learn to improve learning motivation.
Q 5	This teaching can help me effectively use diversified information to solve problems.
Q 6	This teaching can improve my ability to integrate theory and practice.
Q 7	This teaching can improve my self-learning skills
Q 8	This teaching can improve my critical thinking.
Q 9	In the course, my ability to digest the problem can be improved.
Q 10	In the course, the teacher can guide the students to solve the problem.

TABLE II
TEAM ENGAGEMENT LEVLE

Q 11	Through this topic, I can understand that teamwork is very important for the training and development of organizational skills.
Q 12	For the theme of this topic, team members can coordinate with each other, decide the direction of discussion and work together.
Q 13	This teaching method can enhance my ability to work and communicate with others.
Q 14	In the process of exploring the topic, I can share the information collected and discuss with the team members.
Q 15	In the process of exploring the topic, the team members can express different opinions in the discussion and let me learn different expression skills.

TABLE III
TASK ACHIEVEMENT

Q 16	I and the team members can fully discuss and agree on the work to be done on the topic.
Q 17	In cooperation of the team, I can actively participate in and actually complete the assigned work tasks.
Q 18	In the course, I can properly carry out self-learning planning and manage work to improve the effectiveness of my study.
Q 19	The teaching method of this topic can improve my ability to solve problems.

TABLE IV
COURSE SUMMARY

Q 20	Through the teaching methods of this topic, I can cultivate my ability to think independently and work within groups.
Q 21	Overall, this topic has positive effects for my practical study.
Q 22	I actively participated and studied hard in this special course.
Q 23	Regarding the teacher's teaching on this topic, do you think there is still room for improvement?

Result and Discussion

This course plans to use 3D printing to improve student learning outcomes. Therefore, special attention will be paid to student learning skills, teamwork and execution. There are a total of 23 questions in the questionnaire test. The questionnaire survey before the implementation of the course has been completed. The ability to explore the creative design of students and the virtual and real situational transition is evaluated in the first 10 questions. The results of these 10 questions are shown in Figure 3 to 6. The total number of people surveyed is 84.

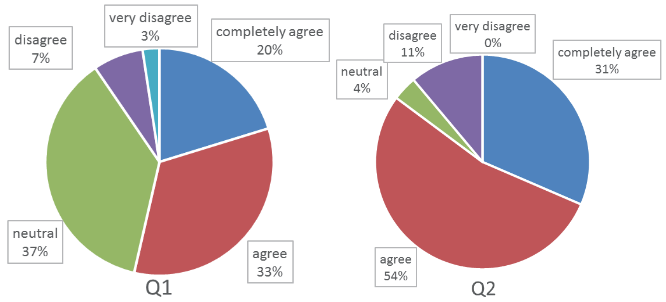

Fig. 3 Statistical results of the question 1 and 2

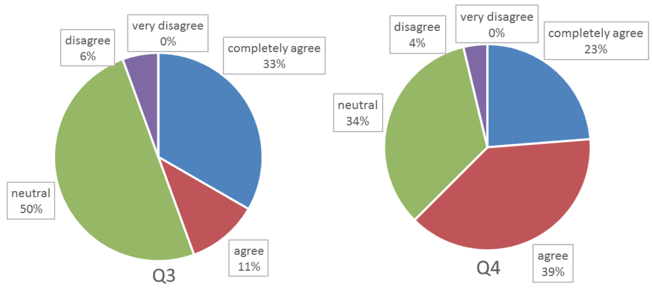

Fig. 4 Statistical results of the question 3 and 4

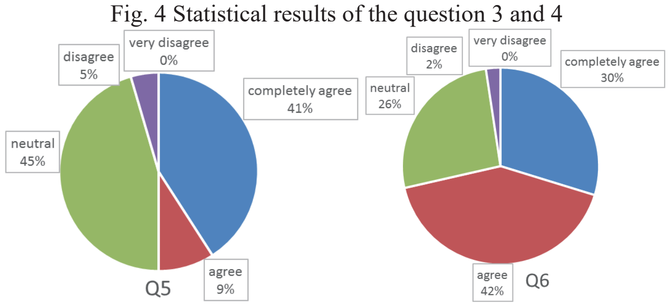

Fig. 5 Statistical results of the question 5 and 6

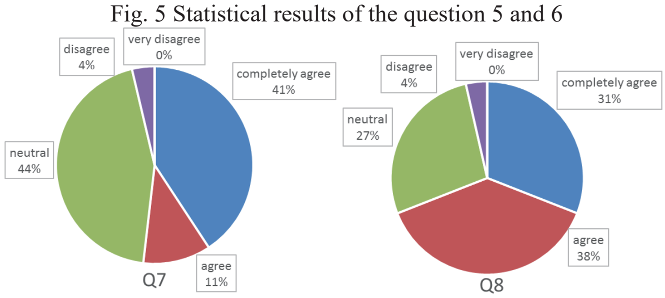

Fig. 6 Statistical results of the question 7 and 8

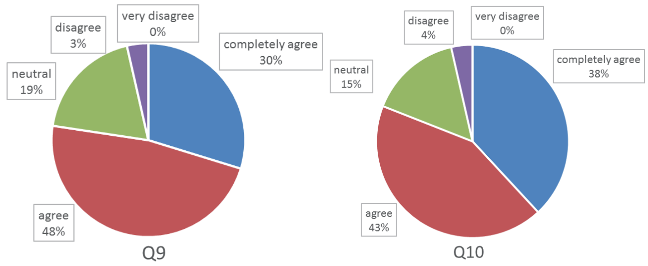

Fig. 7 Statistical results of the question 9 and 10

The main scope of this course is to confirm the learning outcome through the development of small-sized accessories. The courses for mechanical component design, definition of design requirements (Mind map), and patent search and avoidance have been completed (Figure 8). Student grouping and content discussions are currently undergoing. After the product features are clearly defined, the 3D drawing will be utilized and the concept will be materialized by 3D printing.

(a) (b) (c)

Fig. 8 (a) Courses for mechanical component design; (b) Define design requirements; (c) Patent search and avoidance

Conclusion and Future Work

According to the results of the questionnaire test (pre-course), the agreement (four points or more) of question 1, question 3, question 5 and question 7 was less than 60%. Further analysis discovered that the key issue was related to the implementation of the courses. Since the result was done before the course started, the students were doubtful whether the course and 3D printing could improve the ability of mechanical component design. However, as the course is running, students' response to the transition between virtually and reality is gradually increasing, especially in the presentation and expression of mechanism functions. There are two future works for this study. Firstly, the 3D drawing and 3D printing of the product will be completed in order to further implement the virtual and real situational transition barriers. In addition, a questionnaire test (post-course) will be given to the students in the end of the course. By analyzing the results of the two tests (pre and post course), the improvement of the students in mechanical component design will be discussed in more depth.

Acknowledgement

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