*International Journal of Engineering Education* Vol. 36, No. 4, pp. 1136–1150, 2020
Printed in Great Britain
0949-149X/91 $3.00+0.00


# Action Research on Integrating Maker Spirit and Maker Space for the Special Topic Courses of Engineering Students in Vocational High Schools*

CHIH-CHAO CHUNG
General Research Service Center, National Pingtung University of Science and Technology, 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan. E-mail: ccchung@mail.npust.edut.tw

CHENG-LUNG TSAI
Department of Industrial Technology Education, National Kaohsiung Normal University, 62, Shenjhong Rd., Yanchao District, Kaohsiung City 82446, Taiwan. E-mail: lexus001379@gmail.com

YUH-MING CHENG
Department of Computer Science and Information Engineering, SHU-TE University, 59, Hengshan Rd., Yanchao, Kaohsiung County 82445, Taiwan. E-mail: cymer@stu.edu.tw

SHI-JER LOU**
Graduate Institute of Technological and Vocational Education. National Pingtung University of Science and Technology, 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan. E-mail: lou@mail.npust.edu.tw

This study aims to integrate Maker Spirit and Maker Space to establish Maker Space courses for engineering students in higher vocational schools, and explores students' feedback and learning effects in their expression of the Maker Spirit and the utilization of Maker Space in the learning portfolio. This study adopts Action Research, and takes 43 second-year engineering students in special topic courses in higher vocation schools as the subjects. This research covers the teaching of one semester, and relevant qualitative and quantitative data are collected for statistical analysis. The research results are, as follows: (1) Maker Space courses have significant positive effects on students' expression of Maker Spirit, the utilization of Maker Space, and Learning Outcome; (2) Maker Space courses can lead students towards seven Maker education objectives; (3) the teaching model of the Maker Space courses includes seven focuses in the implementation of curriculum and seven educational objectives. Finally, this study summarizes the research results, and provides suggestions for teaching application and future studies.

**Keywords:** Maker Spirit; Maker Space; engineering in higher vocation education schools; special topic courses; Action Research

## 1. Introduction

The rise of the Maker movement around the world has contributed to the prevalence of Maker education. The United States is the birthplace of the Maker movement. According to the 10-year "Educate to Innovate" Program, as proposed by American President Barack Obama, the US will spend US$400 million (about NT$12 billion) in training 100,000 teachers to promote the "learning by doing" and create more Maker Spaces. Moreover, American teachers are suggested to follow the Maker Spirit to integrate knowledge through learning-by-doing tasks, in order to make learning more interesting and practical [1, 2].

In Taiwan, increasing attention has been paid to the Maker Spirit, and educational departments and schools have invested a tremendous amount of money in space planning and equipment purchase. In 2014, the Executive Yuan launched the vMaker Program to develop Maker power in three stages [3]. Due to the increase in the percentage of overall educational funds since 2016, the Ministry of Education has been able to create a special fund of about NT$90 million to implement a 5-year program – Innovative Maker Promotion Program for Higher Middle Schools. It is predicted that more Maker labs will be established to improve the 3D Maker equipment of different schools and activate their technological teaching centers [4]. This program aims to develop students' ability to apply knowledge to life, give them the sense of achievement brought by creation, and even help them interact with international communities and organizations to strengthen Taiwan's competitiveness [5].

Many present students in higher vocational education schools chiefly focus on the subjects of entrance examination as well as repeated practice for proficient skills, which aim at acquiring relevant skill certificates, rather than actual professional skills needed in the workplace [6]. As a result, business owners are skeptical about the professional

** Corresponding author.


* Accepted 5 February 2020.

technical capability of vocational graduates. Therefore, if the Maker spirit can be integrated into a school's curriculum, and the creative topics that students are interested in can be scheduled into it, then students should be attracted to take part in the curriculum and carry out practical operations with the right mindset. Thus, the objectives of Maker education can be achieved, and students' ability at problem solving and practical application can be improved [7].

As the Maker program enters the educational system and becomes an official or unofficial course, it is necessary to conduct systematic planning and evaluation to ensure the direction and benefits of Maker education. Therefore, Yeh, Cheng, Lou, and Shih [8] conducted an interactive demonstration and integration of Maker education, and determined three core concepts, namely, "Practice", "Teamwork", and "Knowledge sharing". Maker education emphasizes the practice of students and aims to develop students' abilities to innovate, think critically, solve problems, cooperate, and communicate with others. All such abilities are essential and required by students in the 21st century [9].

This study considered the implementation of the Maker blueprint, as drawn by the Ministry of Education, and integrated Maker Spirit and Maker Space to establish Maker Space courses for engineering students in vocational high schools, which aims to help students put their creative ideas into practice and improve their Maker mindset and skills. The four objectives of this study are, as follows:

(a) To probe into engineering students' expression of the Maker Spirit in the Maker Space courses of vocational high schools.
(b) To understand engineering students' utilization of the Maker Space in the Maker Space courses of vocational high schools.
(c) To analyze engineering students' learning effects in the Maker Space courses of vocational high schools.
(d) To establish a teaching model for the Maker Space courses of vocational high schools.

## 2. Literature Review

Academic papers regarding Maker Space, Maker Spirit, and Maker education are discussed according to the research objectives.

### 2.1 Maker Space

The Maker Space is the learning domain of the practice community, and community members play the most important role. To facilitate interaction and co-working among makers, it is necessary to adopt some activities to make learning occur simultaneously. Maker is a new self-learning identity; to be more specific, it is hoped that recognition of the maker identity will provide students with opportunities and platforms to practice in professional fields. In the *Maker Space Manual (School Version)*, Peppler and Bender [10] mentioned 10 ways to introduce the Maker movement to education:

(a) Create an environment that nurtures the Maker mind, and the ever-growing Maker mind can motivate students and make them confident that they can learn everything.
(b) Design an educational system that can train a large group of Makers.
(c) Design and develop Maker Spaces in diverse communities to serve the people who do not have access to the same Maker resources.
(d) Utilize diverse tools and materials to develop and share the projects and item frameworks that connect the on-campus and off-campus hobbies of students.
(e) Design and operate an online social platform that allows interaction and cooperation among students, teachers, and communities.
(f) Make a scheme mainly for young people where they can play a leading role and develop more Makers.
(g) Provide communities for the exhibitions and planning of Maker students, and create new opportunities for the participation of more people.
(h) Allow individuals or groups to make participation records of Maker communities, which will promote students' academic and occupational advancement.
(i) Establish an educational environment that links practice and creation with standard concepts and theories; support discovery and exploration; use new tools in advanced designs and apply the thoughts of Maker activities to new methods.
(j) Develop all students' all-rounded abilities, creativity, and confidence, in order that they will become promoters able to change their life and community [11].

### 2.2 Maker Spirit

The Maker Spirit focuses on active creation rather than passive acceptance; it encourages sharing and cooperation instead of competition; it proceeds from interest and provides continual motivation; all ideas can be put into practice. Many scholars have agreed that the practice-oriented learning portfolio can strengthen students' ability to absorb knowledge and innovate [9, 12, 13]. As underlined by all makers and inventors in the world, invention would not occur in the reading of theories, but in the process of practice; meaning inventions would not be made unless the theories and methods of different subjects are employed to solve problems in the real world [1].

Therefore, this study summarizes the meaning of the practice-oriented portfolio. In addition, to helping students acquire complete knowledge, it aims to equip students with the abilities to innovate and think independently, have active motivation, and develop their problem-solving abilities.

### *2.3 Maker Education*

The 12-year National Basic Educational Curricular Outline is based on core quality, and its principles of "simultaneity, interaction, and common good" are consistent with the spirit of the Maker movement – "sharing and co-creation". According to Wang [14], schools should be encouraged to plan Maker courses and incorporate Maker education into interdisciplinary subjects; schools of all levels can make good use of Maker Space, plan Maker courses in their curricula, create distinctive features, and encourage students to develop Maker skills [15].

According to Chu and Tseng [5], Maker education must start from schools, focus on students, and be added with core quality factors; students should be taught to constantly try new things through practice, in order to develop their abilities to think, share, and make; more Makers should be developed. In addition, opportunities should be offered to students to build self-confidence through the sense of achievement brought by practice. Students should develop from experience-oriented learning to in-depth learning, and then, to active learning. Last, but not least, innovation appears in entrepreneurship and enhances human quality [16].

This study summarizes the studies of Maker education, as shown in Table 1, and considers the main points, as proposed by Liu [9], to implement the Maker education program, including (a) "Students can give a play to their initiative", (b) "Putting students' ideas into practice is taken as the main objective", (c) "Students can understand their creations", and (d) "Students can show their problem-solving ability and confidence". These main points are adopted as important reference for the design of the Maker Space courses for engineering students of vocational high schools in this study.

## 3. Research Design

The research design was created according to the research objectives and literature review, and is detailed, as follows:

### *3.1 Research Process*

This study incorporated Maker Spirit and Maker Space into a curriculum to create Maker Space courses for engineering students for one semester in vocational high schools. Both qualitative and quantitative research methods were employed for this Action Research. The students' feedback and feeling were summarized in a learning portfolio to discuss the effects of the courses on students' expression of the Maker Spirit, as well as the utilization of the Maker Space, which were taken as the reference for modification of the Maker Space courses in this study (see Fig. 1).

**Table 1.** List of the Studies on Maker Education and Maker Movement

| Author | Description |
|---|---|
| Dougherty [17] | The Maker movement should be incorporated into the educational field, and many learning strategies should be included to achieve this objective. |
| Kurti, Kurti & Fleming [18] | The students in Maker education have the right to make their own decisions. They would maintain their passion for learning and become more confident in learning after developing the abilities to detect, analyze, and solve problems. |
| Graves [19] | It is suggested that schools have initiators and like-minded people who are committed to Maker education, and purchase Maker equipment when starting to operate a Maker Space. Then, they should establish Maker communities and workshops, integrate Maker education with standard curriculums, and take other measures. |
| Yeh, Cheng, Lou, and Shih [8] | Maker education has three core concepts, namely, "Practice", "Teamwork", and "Knowledge sharing". It is designed to help students acquire theories, put them into practice, and develop a positive Maker's mindset. Moreover, it motivates students to participate in group activities and cooperative learning, and become willing to share their knowledge and experience. |
| Lin [20] | When designing Maker education activities, schools should include learning strategies, in order that students can have their own stories about practice. The benefits they gain in practice will be much greater than the finished products on display. |
| Chang [16] | The benefits of Maker education include developing students' confidence through the sense of achievement brought by practice, introducing experience-oriented learning, in-depth learning, and active learning, nurturing students' creativity and entrepreneurship, and enhancing student quality. |

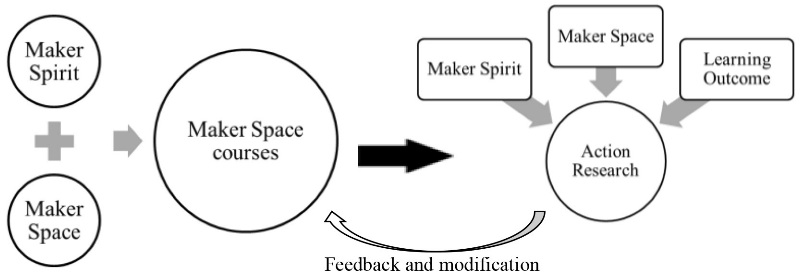



**Fig. 1.** Research procedure.

*3.2 Research Subjects*

The subjects of this study were selected according to the research objectives, and purposive sampling was adopted. The vocational high schools that had established Maker Spaces and intended to introduce Maker courses, but had not planned relevant courses, were chosen as the subjects. Regarding the department and major, automobile service students with the knowledge of basic industries were selected, as they would be able to focus on learning in a Maker Space and apply the Maker Spirit in the implementation and development of the Maker program. The case schools were vocational high schools featuring normal placement in southern Taiwan. According to the research objectives of this study, 43 second-year engineering students attending Maker courses were chosen, and were divided into nine groups for the Action Research of this study.

*3.3 Research Method*

In this study, Action Research was used for analysis of the expression of the Maker Spirit and the utilization of the Maker Space of engineering students attending Maker Space courses in vocational high schools. Action Research is a self-examination and self-assessment method designed to explore processes and improve teaching [21]. The Action Research of this study is divided into four stages:

(a) Creating the action scheme: the scheme of Design and Activity Planning of Maker Space Courses was proposed according to the literature review.
(b) Implementation of the action scheme: the Maker Space courses were offered, and collection, analysis, and comparison of the data were continually conducted.
(c) Evaluation and review of the action scheme: the questionnaire method and focus group interviews were adopted to evaluate the effects of the Maker Space courses.
(d) Re-implementation of the modified action scheme: qualitative and quantitative research methods were used to evaluate and modify the results, in order to establish the Teaching Model of Maker Space Courses, which were used as the basis for the launch of the courses, and its effects were re-evaluated. The research focus was placed on the implementation, evaluation, and modification of the Maker Space courses.

The questionnaire method, document analysis method, and focus group interviews were employed to collect data. In terms of the implementation of the questionnaire, this study created a Questionnaire on the Learning Effects of Maker Space Courses. The official questionnaire was created upon the questionnaire draft, the analysis of content validity, preliminary testing, and analysis of reliability and validity. (The analysis result is described in 3.5.) The questionnaire was conducted before and after the teaching and was taken as the basis of the learning effect analysis. The questionnaire was designed to determine whether the students improved their expression of the Maker Spirit, their utilization of the Maker Space, and their Learning Outcome after taking the Maker Space courses, and to determine the overall teaching efficacy. The results can be applied to improve teaching methods.

In the implementation of the teaching portfolio in this study, the students' written reports and creations were collected, and their interaction texts were collected through online platforms. All such materials were taken as the material sources of the document analysis method, and were used to further understand the students' learning behaviors and phenomena.

Finally, this study utilized focus group interviews to collect data; the student groups were transformed into focus groups for in-depth interviews. In the process, the researcher and the participators described their experiences, discussed the topics, and conducted interactive demonstrations, which intended to obtain organized and in-depth written information to support the questionnaire and document analysis method, and thus, enhance the accuracy of this research.

In order to ensure the reliability and validity, this study involved some specific practices. In terms of reliability, the presentation of data was based on the original records taken from teaching setting, and the data were presented in great detail. In terms of validity that focused on analysis during the study and after data collection, researchers and teachers carried out continual analysis and discussion on the data, so as to provide greater consideration on different aspects of the study, reduce subjective prejudice and negligence, and achieve wider consensus [22].

### *3.4 Design of Maker Space Courses*

This study sorted the suggestions on Maker education, as proposed by Kurti, Kurti, and Fleming [18], Dougherty [17], Liu [9], Yeh, Cheng, Lou, and Shih [8], Chang [16], Lin [20], and Chu and Tseng [5], and summarized the 10 ways to introduce the Maker movement into education, as stated in the *Maker Space Manual (School Version)* [11]. In addition, the seven key factors in the design of Maker Space courses for engineering students in vocational high schools are introduced, as shown in Fig. 2, and described, as follows:

(a) Students as the center
The Maker Spirit, which regards students as the center, was taken as the curricular objective of the Maker Space courses, and the demands for automobile-related knowledge, skill acquisition, and application of the second-year automobile service students in vocational high schools were taken as the main axis. The curricular application covers professional knowledge and skills regarding dynamic machinery, engines, base, and mechanic equipment, as well as pollution emission control technology. The above course focuses were integrated and Maker Space activity tasks were planned to design the student-oriented Maker courses.

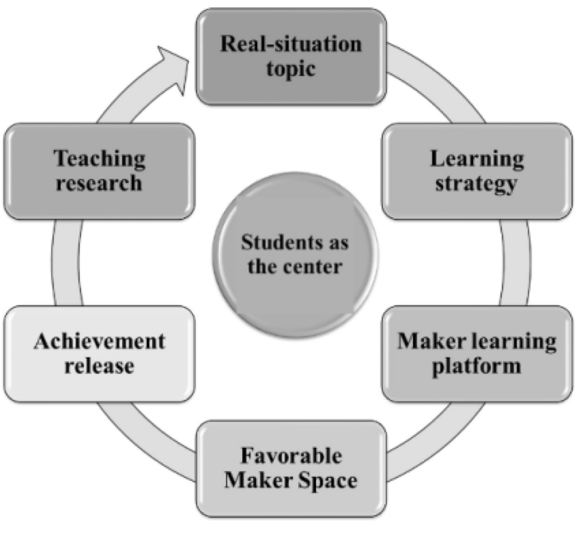



**Fig. 2.** Seven designs for the Maker courses.

(b) Real-situation topic
Practical topics were planned according to the daily life situations of the students. The theme in this study is "Creative designs on the Internet of Things for Automobiles", and students were encouraged to think about the topics related to the danger and inconvenience of driving. Moreover, the students were directed to deliberate on real problems, and solve them via the creative integration of the Internet of Things technologies, in order to make driving safer, more convenient, and more human-oriented.

(c) Learning strategy
In the Maker Space courses, Problem-Based Learning (PBL) as a learning strategy was incorporated into Maker teaching, which adopted effective learning rules, approaches, skills, and adjustment methods, in order to improve learning quality and efficiency.

(d) Maker learning platform
To satisfy student demands in the digital generation, the Maker Learning Line Community was established for the Maker Space courses in this study, in order that the students would be able to study, discuss questions, sharing experiences, and communicate with each other at any time. Moreover, the platform could be used by teachers to release information, upload additional learning materials, assign homework, interact with students, offer consultation service, understand the students' learning progress, and collect the textual materials of the students.

(e) Favorable Maker Space
To create a favorable Maker Space environment, this study planned the Maker Talent training mechanism. All Maker Space machinery items were selected and maintained by a group of students, including a drilling machine, milling machine, turning machine, grinder, digital ink-jet cutting machine, laser engraving machine, 3D printer, metal printer, and thermal transfer printer. In the first one or two weeks, the teachers taught all the students how to safely operate the selected machinery items, in order to enhance their Maker Talents with machines. Then, the peer learning approach was adopted, and each group was asked to learn something of the Maker Talents required for other machinery items; each student was required to learn how to safely operate another machine one by one every two weeks, and gain certification from the teachers, thus, becoming a Maker Talent of the designated machines; any student that failed to achieve this requirement

would be instructed by teachers during extra learning hours. In this way, the operation obstacles, as caused by students' unfamiliarity with operation and fear in the use of the machines, would be eliminated, and the students would become willing to use the Maker Space equipment and resources, thus, increasing the usage rate of the Maker Space. After one semester, almost all the students knew how to safely operate all the given machines.

(f) Achievement release
This study planned to release the actual Maker achievements of the students on a platform to share their design principles and practice experience, and display their creativity and achievements. Moreover, links leading to resources about innovation and entrepreneurship were offered.

(g) Teaching research
This study emphasized the efficacy of curriculum implementation, and planned research on the teaching of the Maker Space courses. Both formative and conclusive evaluations were conducted to review the efficacy of the courses and the students' learning efficacy. The review results were taken as evidence for the modification and improvement of the courses.

### *3.5 Research Tools*

The research tools of this study include the Maker Space Line group and a questionnaire on the learning efficacy of the Maker Space courses. The Maker Space Line group was designed for the students to engage in online consultation, cooperative learning, group discussion, and experience sharing. In addition, it was used as the main source of the written data regarding the online interactions among the students.

Moreover, this study created a Questionnaire on the Learning Effects of Maker Space Courses, which was combined with focus group interviews to collect data. In the making of the questionnaire, five experts and scholars were invited to test its validity, and the questionnaire was modified to become the official questionnaire, as shown in Table 2. The reliability of the questionnaire was tested with Cronbach's $\alpha$. The Cronbach $\alpha$ values in the subscales of the expression of Maker Spirit (6 items), the utilization of Maker Space (10 items), and Learning Outcome (13 items) are 0.94, 0.90, and 0.88, respectively, and the Cronbach $\alpha$ value of the scale is 0.94, which indicates the internal consistency of the scale. The test was conducted after the activities, and One-sample t Testing was adopted for analysis.

In addition, the qualitative data about the students' learning portfolio came from "interviews (I)", "the discussion records of the Maker Space Line (D)", and "written achievement reports (R). The researcher transcribed the interview results, and sorted and encoded the abovementioned qualitative data. Moreover, the researcher read the data several times, marked the main points, and defined the main axis and selective codes to explain the relationship between the results presented by the research institute and the phenomena [23]. This study offers the data sources in the form of codes; for example, "(20181121D-A1)" refers to the data regarding No. 1 student in Group A in the discussion zone of the Line group on November 21, 2018.

## 4. Results

According to the implementation of the research design, the quantitative analysis of the students' learning efficacy and qualitative analysis of their learning portfolios in the Maker Space courses are, as follows:

### *4.1 Analysis of the Learning Efficacy of Maker Space Courses*

This study analyzed the learning efficacy of 43 students attending the Maker Space courses. The questionnaire consists of three dimensions, "Expression of Maker Spirit", "Utilization of Maker Space", and "Learning Outcome". One-sample T testing was employed for statistical analysis. The means of the 3 dimensions are taken as the test value (common value), and the purpose is to determine whether the relationship between students' actual performance and the common value reaches a significantly positive difference. The analysis results are shown in Table 3, which are detailed, as follows:

#### *4.1.1 Expression of Maker Spirit*

The mean of the expression of Maker Spirit is 4.50, and the t value is 13.02 ($p < 0.001$). The means of the items stayed between 4.36 and 4.59, meaning they all reached the significant level (0.001). "Maker Spirit features practice" has the highest score ($M = 4.59$), followed by "Maker Spirit, which is characterized by sharing", while "Maker Spirit emphasizes independent learning" ($M = 4.52$). This shows that Maker Space courses have positive effects on students' expression of the Maker Spirit.

The students enjoyed practicing while participating in the program, as they could experience the benefits of creation and sharing, and have the sense of achievement brought by making a customized product through a complete procedure. By attending the Maker Space courses, the students could develop the habit of independent learning and become keen on creative thinking. Moreover, they

**Table 2.** the Questionnaire on the Learning Effects of Maker Space Courses

| | **Item** |
|---|---|
| Maker Spirit | I know the Maker Spirit has the feature of Do It Yourself |
| | I know the Maker Spirit has creativity |
| | I know the Maker Spirit has the feature of sharing |
| | I know the Maker Spirit has the feature of customization |
| | I know the Maker Spirit is featured by a bottom-to-top procedure |
| | I know the Maker Spirit emphasizes self-directed learning |
| Maker Space | There is access to relevant resource equipment of Maker Space provided by the school |
| | Maker Space can provide Maker gatherings for communication |
| | Cooperative work can be conducted through Maker Space |
| | The curriculum LINE group provides group communication for Makers |
| | The curriculum LINE group provides resources of learning materials |
| | Energy from different Makers can be combined through the curriculum LINE group |
| | Experience sharing can be carried out through the curriculum LINE group |
| | Each person's creativity can be stimulated through the curriculum LINE group |
| | Teachers of this course have planned tasks for the students to finish |
| | With Maker Space, interdisciplinary learning can be done |
| Learning Outcome | I learn to discover problems in the study |
| | I learn to discover problems in life |
| | I learn to think about how to solve problems |
| | I learn to discuss the solutions of problems with others |
| | I learn how to unleash my creativity |
| | I learn how to design and make things |
| | I learn to make a piece of work with my own hands |
| | I learn to make tools or items that can solve problems |
| | I learn how to realize creative ideas |
| | I learn to make final products in accordance with my own design |
| | I have the attitude of self-making |
| | I have the skill for self-making |
| | I have the knowledge of self-making |

**Table 3.** One-sample *t* Testing on the Dimensions of the Maker Space Courses

| **Dimension** | **Average mean** | **Standard deviation** | **Degree of freedom** | ***t*** |
|---|---|---|---|---|
| Expression of Maker Spirit | 4.50 | 0.76 | 42 | 13.02*** |
| Utilization of Maker Space | 4.54 | 0.70 | 42 | 14.53*** |
| Learning Outcome | 4.54 | 0.70 | 42 | 14.52*** |

*** $p < 0.001$, test value = 3.

could develop the abilities to make things and create customized items to express their Maker Spirit.

### *4.1.2 Utilization of Maker Space*

The mean of the utilization of Maker Space is 4.54, and the t value is 14.53 ($p < 0.001$). The means of the items stayed between 4.36 and 4.68, meaning they all reached the significant level (0.001). "Experience can be shared in a Maker Space" has the highest score (M = 4.68), followed by "Interdisciplinary learning can be done in a Maker Space" (M = 4.64) and "Co-work can be done in a Maker Space" (M = 4.59). This shows that the Maker Space courses have positive effect on students' utilization of a Maker Space.

The students could experience the importance of the utilization of a Maker Space; in other words, they agree that a Maker Space gives makers a platform to meet, communicate, and share experience. Therefore, the students would feel motivated to create, be engaged in interdisciplinary learning, and become committed to learning activities. When the students finished the tasks, interdisciplinary integration could be done according to the capabilities of the makers. The students worked as a group to consider and analyze problems from different perspectives, and then, offered solutions.

#### *4.1.3 Learning Outcome*

The mean of the Learning Outcome is 4.54, and the t value is 14.52 ($p < 0.001$). The means of the items stayed between 4.43 and 4.66, meaning they all reached the significant level (0.001). "I have learned how to detect problems in learning" has the highest score ($M = 4.66$), followed by "I have learned how to consider and solve problems" and "I have Maker knowledge" ($M = 4.61$). This shows that the Maker Space courses have positive effect on students' Learning Outcome.

The students learned how to detect problems in daily life and learning, and became active to discuss the topics that interested them. By facing problems, they became brave enough to tackle the challenges, learned how to think independently, and discussed issues with peers to give play to creativity when solving problems. In the process of thinking about how to overcome problems, students could make evaluations according to their creativity, choose appropriate schemes and ideas, and design and make what they expect. Through the courses and the making of things, students acquired Maker knowledge, skills, and attitude.

### *4.2 Expression and Utilization of the Maker Spirit in the Maker Space Courses*

According to the realization of the seven main design factors of the Maker Space courses, Action Research was adopted to observe the students' learning portfolios in the Maker Space courses and collect the records of the group discussions, including the written reports and interview results, for qualitative analysis. The implementation of the Maker Space courses was summarized, and the analysis results of the written data about the cases are explained, as follows:

#### *4.2.1 Designed Student-Oriented Maker Courses: the Students could take the Courses Independently and Simultaneously*

This study designed the Maker Space courses to meet the demands of second-year automobile service students according to the automobile service courses; therefore, the scope of the special topic courses was highly relevant to the compulsory/elective courses for the students, and satisfied students' interest in this occupational subject. Thus, the students could actively collect data and participate in group discussions and cooperative learning, which emphasize the importance of students' learning experiences. In addition, the students independently finished the learning tasks and chose learning resources in the Maker education environment; while solving problems, they engaged in in-depth learning. In this way, students can develop the abilities to detect, analyze, and solve problems. Moreover, it would help them maintain passion for learning and enhance their confidence in learning [18, 24].

> "The theme of the special topic creation for our group was 'Creative designs for the Internet of Things for automobiles'. We could use the knowledge and skills we had acquired in class to make a creative application design that combined the Internet of Things with automobiles." (20190123I-A1)

> "We are automobile service students and will become automobile service professionals. The special topic program – 'Creative designs for the Internet of Things for automobiles' gave us a chance to design new products." (20181121D-A3)

#### *4.2.2 Designed Real-Situation Topics: the Students developed the Attitude and Confidence to Solve Problems in the Real World*

According to Dougherty [17], the Maker movement is closely related to daily life. Learning experience is the outcome of the interaction between students and environment. In this special topic program, the Internet of Things, which is a trend of scientific and technological advancements, was used for the themed design of the Maker Space courses. Centering around "Creative designs for the Internet of Things for automobiles", the students of the pro-

**Fig. 3.** News report about accidents caused by inadequate tire tread depth.

gram collected issues regarding automobiles in real life, and they were free to offer topics for discussion, such as the automobile tire tread depth alarm system and the inner tire difference alarm system. In this way, the students would have the chance to experience the process of applying their knowledge and skills to solve daily life problems, develop the confidence to put theory into practice, and make common contributions to society.

> "We often see news reports about how inadequate tire tread pattern depth results in accidents. Despite the obvious markers on a tire, drivers tend to ignore them, and then, encountered danger, as shown in Fig. 3." (20181113D-A4)

> "According to the research data we collected, inadequate tire tread is one of the three main causes for road accidents. Therefore, our creative product was designed to keep drivers informed of the situation of their tire treads at any time, so as to reduce accidents." (20190123I-A3)

#### *4.2.3 Incorporated Learning Strategies into Maker Teaching: the Students came up with Diverse Creative Ideas and developed their Problem-solving Abilities*

According to the suggestion by Dougherty [17], learning strategies should be included in the introduction of the Maker movement in the educational domain. Therefore, the problem-solving-oriented learning strategy was adopted in the Maker Space courses to design Maker education activities and encourage students to give play to their creative ideas and create their own stories about practice [20, 25]. By planning the practice, the students recognized the problems in the process, and tried addressing the problems. According to the Maker learning task plan, the students finished the following tasks one by one: literature discussion, theme definition, the making of design drawing, creative design and thinking, the solving of practice problems, the writing of written reports, and the release of achievements. Emphasis was placed on the process of the students' exploration and commitment; in this way, the students were expected to develop the abilities to innovate, think critically, solve problems, and cooperate and communicate with others, as all these abilities are essential for students in the 21st century [9].

> "We installed the RFID wafer in the tire. Each wafer has a group of codes. Once the wafer was monitored, the wafer codes would be read. In this way, a tire would have an identity code." (20181128D-A1)

> "The creative design principle of our product is, as follows: Arduino control was adopted with a dashboard equipped with LED display, as shown in Fig. 4. With this product, drivers would be able to check if their tire tread depth meets the requirement at any time, and thus, receive an alarm." (20190121R-A2)

> "We hoped to introduce the concept of the Internet of Things to the cross-comparison between the wafer and the E-tag in the tire, so that the transportation department can have effective monitoring and management of roads, and thus, ensure the safety of drivers." (20190123I-A5)

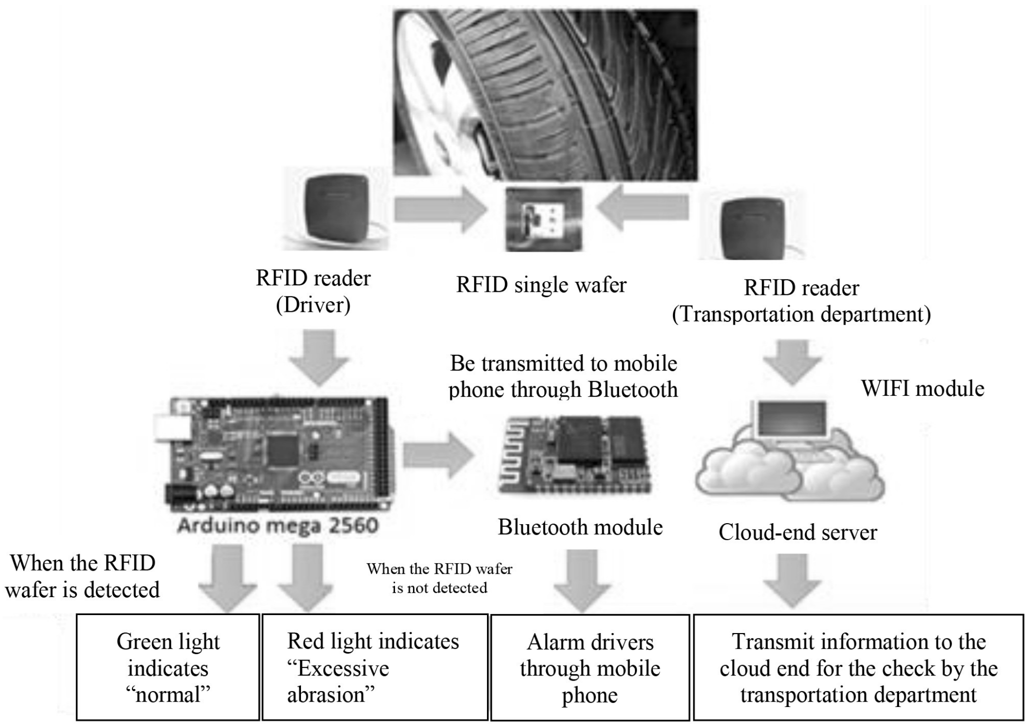



**Fig. 4.** Operation Diagram of Automobile Tire Pattern Depth Alarm System.

#### *4.2.4 Established an Online Maker Learning Community: the Students made good use of the Online Learning Platform to Share Knowledge and Participate in Cooperative Learning*

Following the suggestion by Lin [26], the Maker program established the Maker Learning Line Community is an online platform for interaction and discussion among students, where students could discuss problems and share knowledge and experience. In the Maker Learning Line Community, the students could have efficient group discussions, communication, share, and learn at any time and in any place [8]. For example, after collecting the information about tire, the students could share and discuss the information online and consider solutions to the problems together. They showed their creativity by making a RFID tire function comparison table, and then, used this table to design and make some creative products that could solve unexpected problems in automobiles. In this way, they gave a play to the distinctive features of the Maker education in the digital era, including "practice", "creativity", "sharing", "customization", and "bottom-to-top procedure" [27].

> "I collected some information about tires on the Internet. A tire is mainly made from rubber, and its internal structure can be subdivided into the cover layer and the steel wire ring layer." (20190103D-A5)
>
> "Here is the information for your reference. Tire treads are mainly designed to equip tires with grip, in order that automobiles can run in a more stable manner. Moreover, when the automobile runs on a wet road, the water would be ejected along the tread pattern, and the tires would have better traction. In addition, the high temperature caused by driving can be lowered with the help of the tire structure." (20190103D-A1)
>
> "According to the information I collected, if the tire pattern depth is inadequate, the braking distance will be lengthened, as the tire pattern increases the friction between tire and ground. Inadequate tire pattern depth would also affect the braking distance. On the Internet, there are graphs showing the relationship between tire pattern depth and braking distance when the speed is lowered from 100 miles/hour to 60 miles/hour." (20190104D-A1)
>
> "We discussed the differences between RFID tires and common tires, and the results of the comparison between the two are shown in Table 4." (20190121R-A2)

#### *4.2.5 Created Favorable Maker Space: the Students were Willing to Practice and Share Interdisciplinary Experience*

This Maker program aims to train students in a Maker Space, and a wide range of machines were available to them. Through the Maker Talent training mechanism, as planned in this study, the students learned to operate the machines, as well as the scientific and technological products of the Maker Space, which facilitated the integration of the students' practice and the Internet of Things, and helped them think about and solve problems in an efficient manner to fulfill their objectives [8, 28]. The practice portfolio of the students of the case group who utilized the Maker Space is shown in Table 5. The students interacted and cooperated with each other, and engaged in co-works, thus, initiating the process of learning in a natural way. In the process, the students discussed the machinery integration of Arduino, the application of the Internet of Things, 3D shaping technology, and other valuable "knowledge". In addition, they participated in some valuable "activities", such as group discussions, the acquisition of interdisciplinary knowledge, and the sharing of their practical experiences in function testing and installation. By providing the Maker Space with machines, this Maker program created a favorable environment for the students to meet, discuss problems, share, and use digital devices, make tools, and share programming technologies and skills. Moreover, it was equipped with interdisciplinary knowledge and skills to stimulate each student's creativity [29].

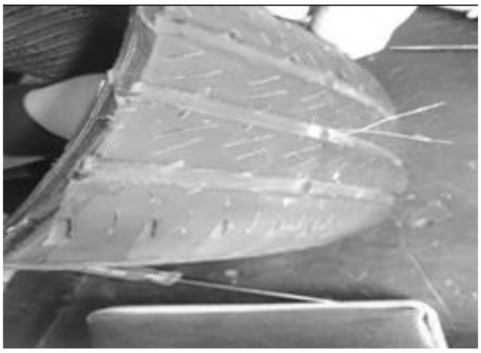
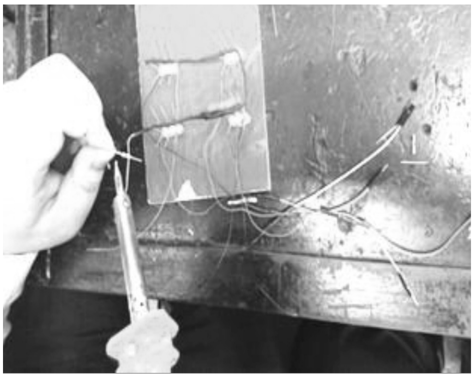
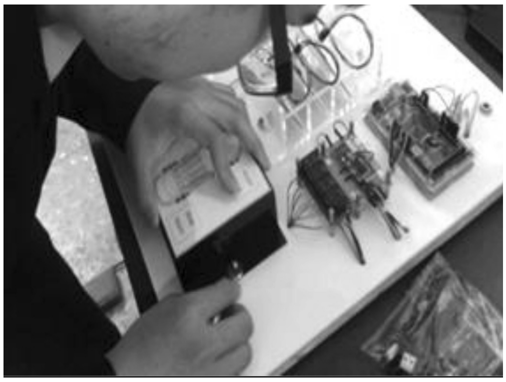
#### *4.2.6 Release Meeting for the Maker Achievements: the Students Displayed their Entrepreneurial Genes, and the Spirit of Sharing and Co-working*

According to the Maker program, the Release Meeting of Maker Achievements was held after

**Table 4.** Students' Records of the Comparison between RFID Tires and Common Tires

| Item | Common Tires | RFID Tire (System) |
|---|---|---|
| Tire pattern depth alarm | Make judgment according to the abrasion markers on the tire. | 1. The abrasion markers on the tire.<br>2. The RFID wafer tire pattern alarm. |
| Function of immediate notification | It is necessary to observe the abrasion markers on the tire. | The conditions of the four tires can be shown on the dashboard. |
| Function of wireless transmission | None | The information is transmitted to a mobile phone through Bluetooth. |
| Utilization of the Internet of Things | None | 1. It can be adopted by the transportation department to facilitate control over the roads.<br>2. It gives a timely alarm about the tire condition through a mobile phone. |

**Table 5.** Practice Portfolio of the Students of the Case Group Who Utilized the Maker Space

| | |
|---|---|
| <br>Step 1: RFID is installed in the inner side of the tire and the reading test is conducted. | <br>Step 2: Wire is extracted from the edge of the abrasion marker. |
| <br>Step 3: The RFID disconnection and connection tests are conducted. | <br>Step 4: The RFID module is laid out. |
| <br>Step 5: The LED lights are installed and the circuit is tested. | <br>Step 6: The parts of the automobile tire pattern alarm system are installed on the display platform. |

the Maker Space courses. Some innovation and entrepreneurship experts were invited for assessment and consultation. In addition, links leading to entrepreneurship resources were offered to develop the students' creative thinking and their ability to innovate, and inspire them to start new businesses [16]. Through the release meeting, the students could showcase their products and the functions of these products; for example, if the reader could not detect the RFID wafer in the tire, the red LED light will be turned on as an alarm, as shown in Fig. 5, 6, and 7. The students showed their creative design ideas of installing the wafer bar codes on the tire, and using Bluetooth to give an immediate alarm to drivers. Through the sharing of creative ideas and mutual interpretation among the groups, the students could share their knowledge and practical experience, and thus, showed the interdisciplinary spirit of sharing and co-working according to the principles of "learn by doing" and "do by learning", as advocated by vocational education.

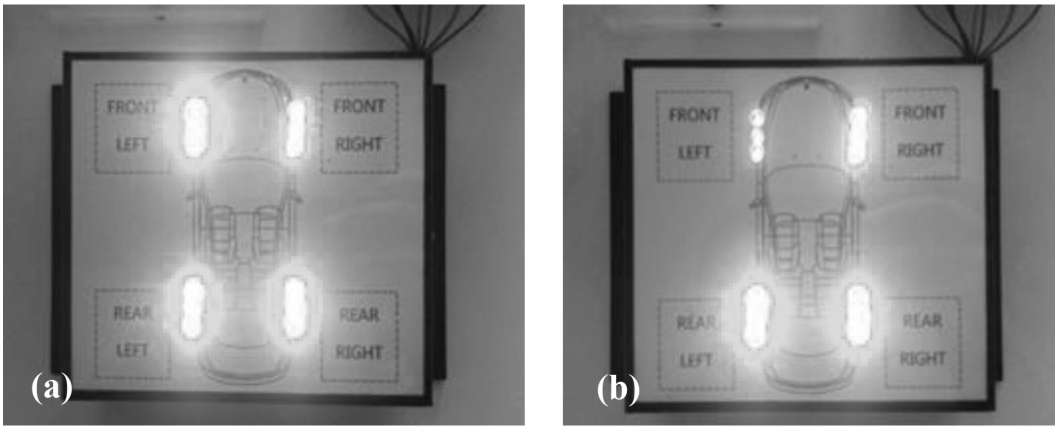



**Fig. 5.** Green light (a) is on in the case of a normal four-wheel wafer, and the red light (b) is on in the case of the abnormality of the left front wafer.

"Our design inspiration came from the Amazon self-service store. When a consumer takes a product from a stack, the sensor would detect the wafer bar codes on the product and send the bill to the consumer's mobile phone. If a sensing wafer is installed in a tire, the sensor would send an alarm signal to the driver according to the abrasion condition of the tire." (20190121R-A2)

"According to our design, the RFID wafer is adhered to the tire, and the reader is used for detection. If the tire is excessively abraded, and the electronic circuit is disconnected by the abrasion, the sensor would not detect the wafer and the red LED light will alarm the driver, as shown in Fig. 5 and Fig. 6." (20190121R-A1)

"In our design, Bluetooth is adopted to transmit signals about the tire conditions to a mobile phone, and the APP on the mobile phone would give an immediate alarm to the driver, as shown in Fig. 7." (20190121R-A1)

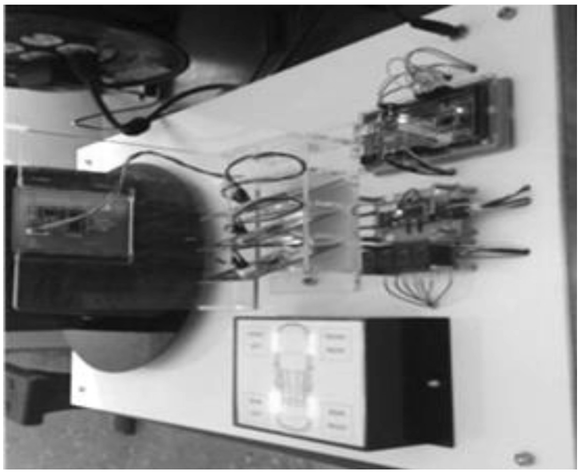


**Fig. 6.** Completion of the automobile tire pattern depth alarm system.


**Fig. 7.** The monitoring information about the tire is shown on a mobile phone.

### *4.2.7 Conducted Research on Maker Teaching: the Students' Learning Efficacy was Reviewed and the Course Implementation Efficacy was Evaluated*

According to Yang and Lin [15], if Maker becomes an official or unofficial course, it is necessary to conduct systematic planning and evaluation to ensure the direction and benefits of the Maker education. Therefore, in the design stage, research on teaching methods was included in the curriculum to observe the students' growth and changes. Moreover, pretesting and a post-testing were conducted for the formative evaluation and conclusive evaluation, in order to review the students' learning efficacy in the Maker Space courses.

In addition, some scholars and experts were invited for professional evaluation of the data regarding the students' learning portfolio and analysis results, and they offered some suggestions according to the evaluation. A design and implementation model for the Maker Space courses was established, and the educational objectives of the courses were set, as shown in Fig. 8. There are seven design and implementation points and seven educational objectives, which can be used as reference information for the introduction of Maker Space courses in vocational schools.

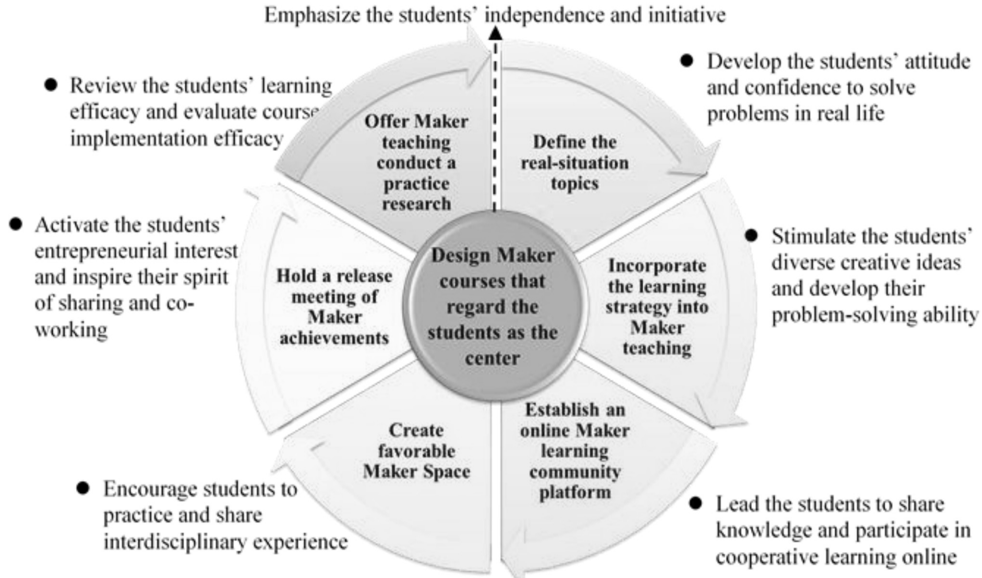



**Fig. 8.** Design focuses and educational objectives of the Maker courses.

## 5. Discussions and Suggestions

This study incorporated Maker Spirit and Maker Space into special topic courses for second-year engineering students in higher vocation education schools to design the Maker Space courses. Moreover, action research on teaching was undertaken. The research discussions and relevant suggestions are, as follows:

### *5.1 Discussions*

#### *5.1.1 The Maker Space Courses have Positive Effects on Students' Expression of Maker Spirit, the Utilization of the Maker Space, and Learning Outcome*

These Maker Space courses are offered according to the seven design and implementation ideas: (a) Design Maker courses that regard the students as the center, (b) Define the real-situation topics, (c) Incorporate the learning strategy into Maker teaching, (d) Establish an online Maker learning community, (e) Create a favorable Maker Space, (f) Hold a release meeting of Maker achievements, and (g) Conduct Maker Teaching research), the courses would help students with their expression of the Maker Spirit, and enhance the utilization of the Maker Space and Learning Outcome.

#### *5.1.2 Maker Space Courses can Lead Students towards the Fulfillment of the Seven Maker Educational Objectives*

These Maker Space courses implementation effects were summarized, including (a) Emphasize the students' independence and initiative, (b) Develop the students' attitude and confidence to solve problems in real life, (c) Stimulate the students' diverse creative ideas and develop their problem-solving ability, (d) Lead the students to share their knowledge and participate in cooperative learning online, (e) Encourage students to practice and share their interdisciplinary experience, (f) Activate the students' entrepreneurial interest and inspire their spirit of sharing and co-working, and (g) Review the students' learning efficacy and evaluate the efficacy of course implementation.

### *5.2 Suggestions*

This study has discussed the learning feedback and efficiency of engineering students in higher vocational education schools on Maker Space courses. As the subjects were automobile service students in a higher vocational education school, the results may not be applicable to other academic departments and courses. This is the first limitation of this study. Second, this study is path-breaking research, and thus there were many difficulties in planning and implementing experimental teaching for the experimental group and control group. As a result, action research was conducted to observe any influences on students' learning experience. The results' qualitative and quantitative analyses are not applicable to the research population. This is the second limitation of the study. The following specific suggestions are proposed as a reference for instructors and researchers regarding Maker Space teaching in the future.

#### *5.2.1 Incorporate Maker Factors into Special Topic Courses*

According to the research, Maker Space courses have significant positive effects on students' expression of the Maker Spirit, their utilization of the Maker Space, and their Learning Outcome. It is suggested that engineering teachers in vocational high schools design and implement student-oriented Maker Space courses according to the "Maker Space teaching model". Moreover, they should understand the seven keys concepts regarding the design and implementation of the courses to provide students with experience in Maker activities.

### *5.2.2 Review the Effects of the Implementation of Maker Space Courses*

This study adopted Action Research to collect and analyze the data of students' learning portfolios in Maker Space courses. The findings show that the courses can lead students towards the seven Maker education objectives. It is suggested that the engineering teachers in vocational high schools should incorporate the seven Maker education objectives into the course implementation performance indicators, in order to review the students' learning efficacy.

### *5.2.3 Design Maker Space Courses for Different Industries*

The Maker Space courses in this study were designed for the second-year engineering students in vocational high schools; therefore, the course implementation effects should not be excessively applied to different domains. Despite the Maker movement emphasizing doing what one wants to do, and encouraging students to give full play to their practice ability, some specific regulations are needed to promote Maker education when the Maker movement is introduced to the official educational domain in schools. Therefore, it is suggested that the vocational high school teachers of different fields should conduct action research on teaching according to the teaching model of the Maker Space courses established in this study; they should consider and define the objectives and meaning of Maker education in different fields, develop the distinctive features of their schools and departments, and encourage students to develop their Maker talents.

## 6. Conclusions

According to the questionnaire of this study, most of the second-year engineering students in vocational high schools showed a positive attitude towards the expression of the Maker Spirit, the utilization of the Maker Space, and Learning Outcome after taking the Maker Space courses, and revealed significant differences. This study highlights that systematic evaluation must be conducted to ensure the benefits of the Maker Space courses. According to consultations with and suggestions from experts and scholars, as well as the research regarding the teaching of the Maker Space courses, a Maker Space teaching model that includes the above seven curricular design and implementation ideas and seven educational objectives should be established.

## References


1. C. S. Bin, W. H. Lin and Y. C. Chang, Real learning starts with practice, *Common Wealth Parenting*, **58**, pp. 152–183, 2014.
2. M. A. Halbinger, The role of makerspaces in supporting consumer innovation and diffusion: An empirical analysis, *Research Policy*, **47**(10), p. 2028–2036, 2018.
3. S. Y. Lee, vMaker Plan. Business Next Homepage, http://www.bnext.com.tw/article/view/id/35888, Accessed 11 December 2018.
4. Ministry of Education, *The creative Maker advancement program of senior middle schools*, Ministry of Education, Taipei, 2015.
5. P. S. Chu and S. H. Tseng, Evaluation and analysis of the practice of the Maker education in the 12-year National Basic Educational Curricular Outline, *Taiwan Educational Review Monthly*, **7**(3), pp. 160–163, 2018.
6. D. Dougherty, *Free to make: How the maker movement is changing our schools, our jobs, and our minds*, North Atlantic Books, 2016.
7. S. Papavlasopoulou, M. N. Giannakos and L. Jaccheri, Empirical studies on the Maker Movement, a promising approach to learning: A literature review, *Entertainment Computing*, **18**, pp. 57–78, 2017.
8. J. Y. Ye, Y. M. Cheng, S. J. Lou and R. C. Shih, Analysis of Empirical Research on Maker Education in Taiwan, *Taiwan Educational Review*, **7**(5), pp. 180–188, 2018.
9. M. C. Liu , Principle and practice of the Maker education: the supporting designs that should be focused, *Taiwan Educational Review Monthly*, **5**(1), pp. 158–159, 2016.
10. K. Peppler and S. Bender, Maker movement spreads innovation one project at a time, *Phi Delta Kappan*, **95**(3), pp. 22–27, 2013.
11. Maker Media, Makerspace Playbook: School Edition, Retrieved from http://makered.org/wp-content/uploads/2014/09/Makerspace-Playbook-Feb-2013.pdf, 2019.
12. C. Y. Yeh and S. C. Lou, Analyze the information education in Taiwanese primary schools from the Maker perspective, *Taiwan Educational Review Monthly*, **4**(12), p. 110–114, 2017.
13. L. Martin, The promise of the maker movement for education, *Journal of Pre-College Engineering Education Research (J-PEER)*, **5**(1), p. 4, 2015.
14. L. Y. Wang, The inspiration of the America's development of Maker Space for Taiwan, *Pulse of Education*, (7), p. 163–169, 2016.
15. M. S. Yang and Y. H. Lin, Theory and Practice of the Maker education, *Taiwan Educational Review Monthly*, **7**(2), pp. 29–38, 2018.
16. Y. S. Chang, STEAM Maker cross-domain integration and the implementation of 12-year National Basic Educational Curricular Outline. *Taiwan Educational Review Monthly*, **7**(2), p. 1–5, 2018.

17. D. Dougherty, The maker movement, *Innovations*, **7**(3), pp. 11–14, 2012.
18. R. S. Kurti, D. L. Kurti and L. Fleming, The Philosophy of Educational Makerspaces: Part 1 of making an educational makerspace, *Teacher Librarian*, **41**(5), pp. 8–11, 2014.
19. C. Graves, Starting a School Makerspace from Scratch, Retrieved from https://www.edutopia.org/blog/starting-school-makerspace-from-scratch-colleen-graves, 2019.
20. K. Y. Lin, Review and suggestions on Taiwan's development of the Maker education, *Taiwan Educational Review Monthly*, **7**(2), pp. 6–9, 2018.
21. H. H. Yang and H. L. Tuan, A Cooperative Learning Approach to Improve Senior High School Chemistry Teaching–Action Research, *Educational Research & Information*, **6**(1), pp. 106–123, 1998.
22. M. Q. Patton, *Qualitative Evaluation and Research Methods*. Newbury Park, California: Sage Publications, 1990.
23. S. B. Merriam, *Qualitative Research and Case Study Applications in Education*. Revised and Expanded from ''Case Study Research in Education''. Jossey-Bass Publishers, 350 Sansome St, San Francisco, CA 94104, 1998.
24. K. M. Yusof, A. N. Sadikin, F. A. Phang and A. A. Aziz, Instilling professional skills and sustainable development through Problem-Based Learning (PBL) among first year engineering students, *International Journal of Engineering Education*, **32**(1), pp. 333–347, 2016.
25. K. P. Nepal, Comparative evaluation of PBL and traditional lecturebased teaching in undergraduate engineering courses: evidence from controlled learning environment, *International Journal of Engineering Education*, **29**(1), pp. 17–22, 2013.
26. M. R. Lin, Research on the implementation of the Maker teaching in the internship curriculum in vocational high schools –Taking the Machinery Department as a case study, *Taiwan Educational Review Monthly*, **5**(4), pp. 143–148, 2016.
27. C. S. Wu, Maker Movement, *Journal of Education Research*, (255), pp. 109–110, 2015.
28. D. W. Chang, Y. S. Shih, Y. T. Cheng and Y. H. Wu, Creative workshop of sharing and co-working: different innovation experiments in colleges, *Taiwan Educational Review Monthly*, **7**(2), p. 39–43, 2018.
29. H. Y. Chao, The Enlightenment of Maker Movement on Life Science and Technology, *Technology and Human Education Quarterly,* **1**(3), pp. 1–20, 2015.

**Chih-Chao Chung** is an Assistant Research Fellow of the General Research Service Center in the National Pingtung University of Science and Technology, Taiwan.

**Cheng-Lung Tsai** is a PhD Candidates of Department of Industry Technology Education, National Kaohsiung Normal University, Kaohsiung, Taiwan.

**Yuh-Ming Cheng** is a full Professor of the Computer Science and Information Engineering in the SHU-TE University, Kaohsiung, Taiwan.

**Shi-Jer Lou** is a full Professor of the Graduate Institute of Technological and Vocational Education in the National Pingtung University of Science and Technology, Taiwan.