Using 6E Model in STEAM Teaching Activities to Improve University Students' Learning Satisfaction: A Case of Development Seniors IoT Smart Cane Creative Design

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Abstract

This study treats an "IoT smart cane creative design" as an example, proposes a STEAM-6E project course, introduces IoT new technology into elderly assistive cane creative design, and plans the STEAM-6E project course development and instructional activity design. This study takes 50 health care department students of a vocational and technological college as subjects and implements quasi-experimental instruction. By questionnaire survey, it explores students' learning outcome. The conclusion is shown below. After experiencing the STEAM-6E project course, the health care department students of the vocational and technological college revealed the following: (1) students' learning outcome is significant and positive after the implementation of the IoT smart cane creative design STEAM-6E course, (2) students are significantly and positively satisfied with the IoT smart cane creative design STEAM-6E course, (2) satisfaction with "6E instruction learning outcome" is significant, (3) planning of STEAM-6E course model is student-based with the assistance of teachers. Thus, this study proposes suggestions regarding the application of new IoT technology to smart cane creative design and STEAM-6E project course planning.

Keywords: STEAM, Internet of Things, Smart cane creative

1 Introdction

With the progress of medical technology, human lives are extended continuously, which results in health issues, such as chronic diseases and the physical disability of the elderly. In addition, due to the low fertility rate, the aging of the global population structure becomes more severe, and the number of people who lack self-care competence increases [4]. Hence, coping with health and disease related issues due to population aging with a positive and active attitude and improving the daily quality of life of the elderly through new technology are the directions of new technology development in different countries.

However, as social aging results in fewer children, in order to respond to the said phenomenon, higher education in different countries has started emphasizing interdisciplinary learning to enhance interdisciplinary thinking and the sources of creativity to cultivate talents, as required by future development [3]. Although creativity is a natural competence of humans, it is influenced by family environment and school education [5]. In the cultivation of students' creativity, the development of problems is the base. When students solve the problems they propose, it triggers their intention to continue exploring. Thus, training students' ability to propose and solve problems will significantly enhance their creativity and practical competence [6].

In recent years, STEAM courses, which consist of Science, Technology, Engineering, Arts, and Mathematics, have been emphasized by educational circles of advanced countries, such as the U.S., as such courses provide multi-subject knowledge and learning situations associated with reality. Thus, through engineering design and scientific exploration, it allows students to integrate their conceptual knowledge to develop problem-solving competence and innovative design ability [10]. In addition, in order to guide students' interdisciplinary integrated learning, it adopts the design learning strategy of 6E Learning by Design [11], as proposed by ITEEA in recent years, thus, in the DIY process, students can successively reinforce learning and obtain products by practice.

Therefore, this study constructs the STEAM-6E instruction model, plans the "IoT smart cane creative design" theme, and guides students to recognize the principles and applications of new IoT technology. By the step by step instructions of the 6E model, it makes progress from thinking, idea development, design, and modification to practice. In this process, through the course planning of STEAM integrated thoughts and DIY practice, students solve problems according to

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DOI: 10.3966/160792642019122007009

scientific knowledge, engineering techniques, aesthetic creation, and mathematical competence to validate knowledge content and accomplish the teaching objectives.

2 Literature Review

2.1 Technological Application in Long-term Care

Martínez-Alcalá et al. [7] analyzed 26 research papers, and argued that several smart technology products can lower caregivers' workload and enhance the efficacy of disease management. The application of technological long-term care includes optimal medicine treatment, distance patient monitoring, assistive device technology, distance training and supervision, disease management, cognitive physical fitness, evaluation, and social networks.

In recent years, IoT is leading global smart city development by new applications, such as distance monitoring and competent device management. From the great number of data it acquires, it creates new interpretations and messages for operation. In addition, by sensors (such as RFID, infrared rays, GPS, and laser scanner), it can exchange the messages received by sensors and connect with the internet to accomplish smart identification, positioning, tracking, monitoring, and management [1]. Since it is highly intelligent and diverse, it is widely applied to different fields. However, in this modern era of information, IoT fulfills interaction between humans and objects, and among objects [2].

Thus, by introducing IoT technology, this study aims to guide learners to create smart cane creative design and produce instructional activities, in order to obtain more practical experience for integrated applications of IoT new technology related to scientific knowledge, manufacturing technology, mathematical calculation, engineering construction, and innovation.

2.2 STEAM

Science, Technology, Engineering, Arts, and Mathematics is interdisciplinary instruction, which combines Science, Technology, Engineering, Arts, and Mathematics. With a basic knowledge of mathematics, students can obtain scientific and technological content in the learning process by practicing engineering and art design [8]. However, it did not specifically define STEAM instruction. Scholars of different countries have various interpretations; some explain it from the perspective of creation and integration, while others describe it as students' center of learning [9]. In this study, the course design of STEAM instruction is based on the perspective of creation and is student-centered. It guides learners to obtain more integrated application experience of scientific knowledge, manufacturing technology, mathematical calculation, engineering construction, and creativity by the IoT smart cane creative design and the production of instructional activities.

2.3 6E

The 6E instruction model, as proposed by the International Technology and Engineering Educators Association (ITEEA), refers to Engage, Explore, Explain, Engineer, Enrich, and Evaluate [11], and the 6 steps are shown below:

(1) Engage: it enhances students' curiosity, interest, and engagement.

(2) Explore: it provides students with opportunities to construct learning experience.

(3) Explain: students explain and modify what they have learned.

(4) Engineer (Extend/Elaborate): students apply nature knowledge to manmade issues and adopt concepts, techniques, and attitudes to the main problems to more profoundly comprehend them.

(5) Enrich: it allows students to practice in-depth learning, in order to apply what they have learned to more complicated issues.

(6) Evaluate: it allows teachers and students to recognize the learning effect.

This study conducts a STEAM project course by the 6E instruction model, and guides learners to successively accomplish IoT smart cane creative design and practice activities. Thus, students can more specifically obtain IoT knowledge, smart cane design competence, and STEAM integrated knowledge and competence.

3 Methodology

3.1 STEAM-6E Course Development

Regarding the development of this STEAM-6E course, this study adopted focus group interviews [12], and invited 5 experts and scholars of creative design, STEAM, health care, elderly care, assistive device design, IoT, and smart home as the organizational members in planning this STEAM project course. Through the research team and focus group of experts and scholars, this study generalized and analyzed experts' suggestions to develop and gradually modify the objectives and contents of the "STEAM-6E project course of IoT smart cane creative design", which served as reference for the construction of learning outcome questionnaire.

3.2 STEAM-6E Course Learning Outcome

Regarding the STEAM-6E course learning outcome, this study treated 50 students of a health care department in one vocational and technological college in southern Taiwan as subjects, and a adopted questionnaire survey to analyze the effect of the STEAM-6E course on students' learning outcome. The project course was practiced by group collaborative learning by students that had never experienced STEAM related courses. In addition, this study constructed a mobile learning platform to observe students' learning process and collect feedback.

4 Results and Discussions

4.1 STEAM-6E Course Development

The development of the STEAM-6E course in this study includes course planning and the construction of objectives, analysis, and evaluation of STEAM learning concepts, as well as the construction of the STEAM-6E instruction model, as shown below.

4.1.1 Course Planning and Construction of Objectives

This study invited 5 experts and scholars to plan the STEAM-6E course and establish the objectives. Experts are from industrial and academic circles, and their working years are more than 10 years, including one university professor, one Associate Professor, and three industrial supervisors, as shown in Table 1. This study adopted focus group for discussion, analyzed and generalized experts' opinions and suggestions, developed the "STEAM-6E project course of IoT smart cane creative design", and established the course objectives and content.

Table 1. Experts' backgrounds

Expert	Title	Education	Specialty	Working year	Category
Expert A	Professor	Doctor	Engineering education, creative design and STEAM	15 years	Academic circle
Expert B	Associate Professor	Doctor	Health care, long-term care and STEAM	13 years	Academic circle
Expert C	CEO	Doctoral candidate	Elderly care and assistive device design	14 years	Industrial circle
Expert D	General manager	Master	IoT, artificial intelligence and creative design	16 years	Industrial circle
Expert E	Manager	Master	Smart home and creative design	11 years	Industrial circle

According to the discussion of the expert focus group and analytical results, the objectives of the "STEAM-6E course of IoT smart cane creative design" include three dimensions, the STEAM course, 6E instruction, project knowledge and competence, as well as 17 course objectives. The cores of experts and scholars, are 7.20~8.20. Based on experts' and scholars' suggestions, this study treats 7.00 as the threshold of objectives, thus, they are all included, as summarized below.

(1) Through STEAM-6E course planning and teaching design, students recognize the real problems in daily lives of the elderly, and consider the solutions and applications of the IoT new technology.

(2) Students can obtain STEAM integrated thoughts, generalize and apply their knowledge of the subjects, and acquire experience that combines theory and practice.

(3) Students accomplish their work according to the development idea of the IoT smart cane, creative design, practice and experiment, modification, and re-validation. This study guides students to observe and modify structure designs related to engineering issues.

(4) The DIY practice process, discussion, and analysis allows students to successively solve problems in the manufacturing process and cultivate their problem-solving competence.

(5) By problem-solving through team work, it cultivates students' concepts of collaborative learning, and provides them with peer work experience and a learning environment.

(6) Through the practical experience of IoT new technology introduced smart cane creative design, it develops students' IoT new technology related knowledge and competence.

4.1.2 STEAM Learning Concept Analysis and Evaluation

This study first conducts content analysis on the subjects of the health care department of a vocational and technological college, such as the physical fitness and sports of the elderly, assistive devices of the elderly life, health promotion, and long-term care practices. Upon interview with teachers and STEAM experts, it establishes a knowledge structure for a STEAM course of IoT smart cane creative design, as shown in Table 2. The topic of this study is "smart cane creative design", which requires students to be introduced to new IoT techniques and technology. By STEAM knowledge learning, it guides students to apply old knowledge, learn course contents of long-term practice, daily life experience, and observation to present the instructional tasks of the course through DIY practice.

Table 2. STEAM learning concept of IoT technology introduced in smart cane creative design

STEAM	Learning concept
Science	Active force and counterforce, energy and force, the moment of force, basic electricity, energy conservation and conversion, static balance, dynamic balance, analysis of stress and strain, and center of gravity
Technology	Assembly ability, use of hand tools or machines, creative design, product testing and modification, energy and force, and 2D and 3D computer graphics
Engineering	Computer graphics, use of materials, industrial design, product design, structure design, engineering design, truss-shop welded, practice and evaluation testing, and problem decisions and solutions
Arts	Structure aesthetics, hand tool operational ability, handicraft competence, material evaluation, and application
Mathematics	Speed calculation, switch of quantity of electricity, basic measurement, angle conversion, geometric concept, trigonometric function, algebra, and analytic geometry

4.1.3 Execution Process of the STEAM-6E Instruction Model

The instructional activity development of this study is based on the 6E model. When designing a teaching plan, it follows instructional objectives, integrates STEAM knowledge content and long-term practice course skills, and develops collaborative learning strategy. Figure 1 is the implementation process of STEAM-6E instruction for IoT smart cane creative design. According to course objectives, it constructs the key points of course implementation for teachers and students to confirm feasibility and effectiveness. In addition, it attempts to test whether it matches STEAM knowledge concepts and competence. Moreover, the 6E process emphasizes that students are subjects who accomplish tasks with different phases and outcome results, where teachers play the role of guide for students and respond to their questions.

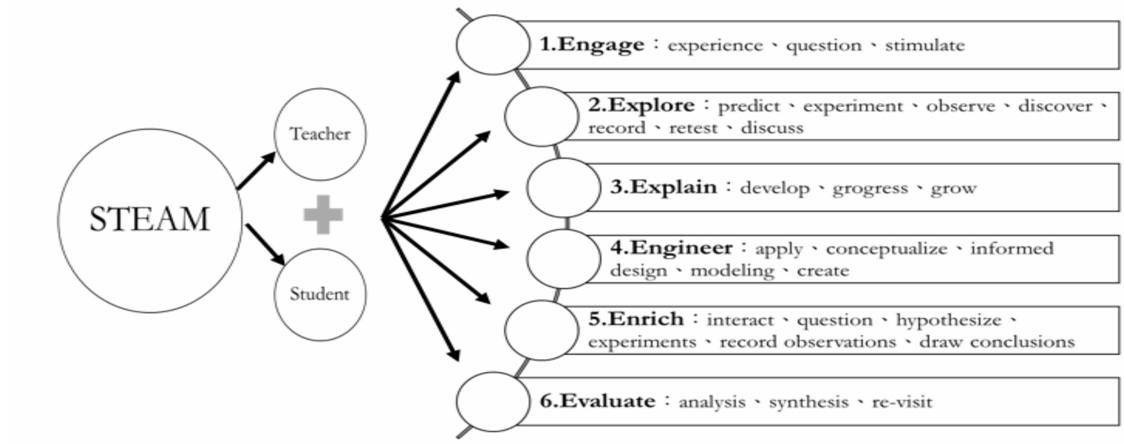

Figure 1. IoT smart cane creative design STEAM-6E instruction model

4.2 Analysis of STEAM-6E Course Students' Learning Outcome

Analysis of students' STEAM-6E course learning outcomes, including analysis of students' learning outcome and learning process, as shown below.

4.2.1 Analysis of Students' Learning Outcome

After the 15-week STEAM-6E project course for 50 students of the health care department of a vocational and technological college, and by pair sample t-testing of the questionnaire survey, this study analyzes students' learning outcomes in the STEAM course, 6E instruction, and project knowledge and competence, as shown in Table 3.

Table 3. T-testing analysis of pair samples of STEAM-6E students' learning outcome

Items	N=50	Average Mean	Standard Deviation	Post-test- Pre-test	t	p
STEAM course	Post-test	4.09	.92	.42	2.46	.018
	Pre-test	3.67	.86			
6E instruction	Post-test	4.14	.83	.37	2.28	.028
	Pre-test	3.77	.81			
Project knowledge and competence	Post-test	4.13	.77	.40	3.41	.001
	Pre-test	3.74	.73			

Regarding the STEAM course, the pretest score of students' learning outcome is 3.67, posttest score is 4.09, and t value is 2.46 (p-value=.018), which reveals positive and significant difference. Thus, after the STEAM-6E course, and by course explanation and practice, in terms of STEAM interdisciplinary integrated learning, most of the students comprehend more scientific knowledge, and show positive attitude regarding effective interdisciplinary integrated learning.

Regarding the 6E instruction, the pretest score of students' learning outcome is 3.77, posttest score is 4.14, and t value is 2.28 (p-value=.028), which shows positive and significant difference. Therefore, after experiencing the STEAM-6E course, most of the students show positive attitude toward the practical experiences of engage, explore, explain, engineer, enrich, and evaluate of 6E.

Regarding project knowledge and competence, the pretest score of students' learning outcome is 3.74, posttest score is 4.13, and t value is 3.41 (p-value=.001), which reveals positive and significant difference. Hence, after experiencing the STEAM-6E course, most of the students obtained IoT and smart cane related knowledge, as well as the current developments and practical experiences of IoT technology introduced in smart cane creative design. Regarding project knowledge and competence learning outcome, they show positive attitude.

4.2.2 Analysis of Students' Learning Satisfaction

This study adopts a questionnaire survey to recognize the satisfaction of 50 health care department students of a vocational and technological college with the STEAM-6E course, as shown in Table 4.

Table 4. Single sample t-test analysis of STEAM-6E students' satisfaction

Items	N	Average Mean	Standard Deviation	t-test value=3
STEAM course	50	4.11	.76	9.60***
6E instruction	50	4.04	.81	8.42***
Project knowledge and competence	50	4.06	.79	8.78***

Regarding satisfaction with the STEAM course, the mean score of students' satisfaction is 4.11 (Standard deviation is 0.76). In comparison to test value 3, it reveals positive and significant difference. Hence, most students are positively satisfied with the STEAM interdisciplinary integrated learning of the STEAM-6E course.

Regarding satisfaction with 6E instruction, the mean score of students' satisfaction is 4.04 (Standard deviation is 0.81). In comparison to test value 3, it shows positive and significant difference. Hence, most students are satisfied with the 6E practice process planning of the STEAM-6E course.

Regarding satisfaction with project knowledge and competence learning, the mean score of students' satisfaction is 4.06 (Standard deviation is 0.79). In comparison to test value 3, it reveals positive and significant difference. Hence, most students are satisfied with project course content, such as IoT, smart technology, current cane development, and creative design of the STEAM-6E course.

4.2.3 Analysis of Students' STEAM-6E Learning Process

The "STEAM project making course of IoT smart cane creative design" of this study is based on the 6E instruction model [11-12] as the main framework, meaning it plans the student-based "STEAM-6E instruction model". The following summarizes students' work, learning sheets, and feedback and by the 6E implementation process, and explores students' learning process and learning outcome regarding STEAM integrated knowledge, IoT techniques, and knowledge and competence in smart cane creative design. The analysis results are shown below:

Engage: It explores realistic life problems and triggers students' learning motivation.

At this phase, this study aims to enhance students' participation in the activity to upgrade their learning motivation. By news reports, pictures, and videos, teachers pinpoint various problems in realistic life situations. Through question development and discussion, teachers allow students to recognize the underlying problems of the events. Thus, students show motivation and interest in problem-solving. This process connects with students' prior knowledge and learning experience to extend their understanding of the importance of STEAM integrated thoughts, and describes the objectives of the course and the activity processes, as well as the expected enhanced competence.

S02: Good project design is based on complete cooperation and team brainstorming. Thanks to the efforts of teachers, leaders, and all members who constantly exchange opinions during both school time and after-school hours to accomplish the written report of this project.

Explore: It guides students to learn STEAM integrated knowledge and cultivates their practical competence of data collection.

Teachers must guide students to collect and learn the course knowledge of IoT, smart cane, and STEAM, thus, they develop students' independent learning abilities, such as data collection, knowledge construction, and learning experience to allow students to gain basic skills to accomplish the project. In addition, they guide students to consider problems related to the topic, and encourage them to participate in discussions and group collaborative learning. In the process, teachers must observe students' discussion quality and situation, in order to help students recognize the problems encountered by the elderly, as well as their real needs, as important reference for future smart cane design.

S02: In daily lives, we often see many people or seniors on the road supporting their bodies by canes to lower physical burden.

Explain: It guides students to explore problems by STEAM integrated thoughts and propose feasible plans.

Teachers guide students to practice case discussion and analysis in order to discover real causes of the problems. Teachers should explain the system concepts to students, and through STEAM integrated thoughts, allow students to practice in-depth thinking to recognize the essence of the problems, and subsequently, encourage students to draw a draft leading to more diverse and creative ideas. Thus, they can discuss the ideas in groups, and consider the possible problems, materials required, and STEAM knowledge applied to develop the optimal feasible plan and construct topics for the smart cane in groups, Please see Figure 2.

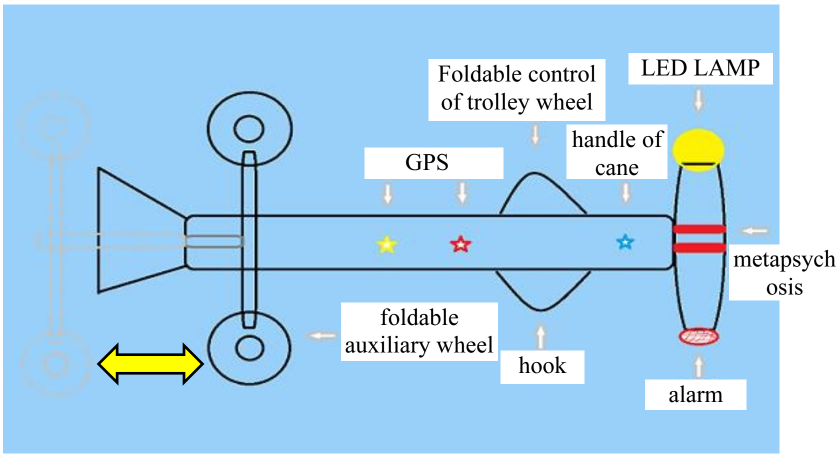

Figure 2. IoT smart cane design

S03: When my grandma went shopping in the market, she walked with the cane while carrying the bags. She might not realize when she lost one of the bags. She might be lost due to Alzheimer's disease, and not know how to return home. These are our sources for creative design.

S01: With such creativity, this cane is no longer a normal one. It combines technology and practicability. Users' lives become more convenient and comfortable. It becomes the best daily partner of seniors after retirement and it protects the elderly at home.

Engineer (Extend/Elaborate): Students apply STEAM integrated knowledge to solve realistic life problems.

Engineering is the practice phase, and teachers should remind students of the points for attention in DIY, such as the selection of materials, the use of hand tools, and operation of manufacturing devices, to ensure that students can accomplish the project safely. Subsequently, teachers should guide students to practice creative design and STEAM knowledge learning, provide students with the necessary assistance and skills, and require students to control the quality and testing of the functions. In the process, teachers should record students' creative processes, as well as the problems encountered, and implement STEAM discussion, testing, and modification, in order to successfully accomplish the tasks of different phases and control students' learning situation and project execution progress.

S03: On the "multi-functional assistive cane" we designed, we installed flexible wheels and hook, thus, the users do not have to carry too many bags while shopping.

S04: The smart cane is installed with a sensor flashlight, GPS, Bluetooth transmission, and sensor for the rhythm of the heart. When seniors walk outside, they can pay attention to their physical situations. Besides, family members can track their location and be relaxed.

Enrich: In-depth and innovative application of STEAM integrated knowledge to solve more complicated problems.

Teachers guide students to extend the design concept based on their original work. Thus, students explore STEAM integrated knowledge to search for broader, and in-depth, and innovative applications. In the process, they require students to write down the creative ideas and the creation processes of the groups as written reports, including extended applications, expansion of engineering concepts, and acquisition of group collaborative learning to accomplish the creative work of the project.

S04: We can observe what seniors require in their daily lives and consider the enhancement of function and safety. It transmits the physical states and locations of seniors by Bluetooth technology and GPS on the mobile phones of family members or caregivers, in order to immediately recognize the location of seniors in abnormal physical state or emergency to avoid regret.

Evaluate: It allows teachers and students to recognize the implementation and outcome of the STEAM-6E course as reference to enhance future course planning.

It includes three kinds of evaluation before, during, and after the course to allow teachers and students to recognize learning outcomes. Before implementation of the course, teachers apply a pretest tool to understand students' learning needs and situations, in order to adjust course contents and progress, and ensure that students' learning is based on course objectives. In the course, they provide tasks in the different phases to allow students to accomplish them, in order to control their learning situation and progress to offer proper assistance. After implementation of the course, they evaluate the effectiveness of the course by a post-test tool.

In addition, by presenting their creative works and creative design concepts, students of different groups engaged in peer exchange and learning, thus, ensuring that students recognize the design, modeling, recourse, and system engineering concepts to solve the problems and accomplish the learning goals of the course. Moreover, in the presentation, they invited the experts and scholars to comment, select, and award the excellent groups to encourage students to extend their learning and research.

S04: Taiwan will soon become a super aged society. It was extremely interesting to develop ideas with STEAM knowledge and design an elderly multi-functional assistive cane. It was also to find ideas to prepare this gift for our future selves after decades have passed.

5 Conclusion

5.1 Conclusion

First, According to the discussion results of the focus group of experts and scholars; it validates that the objectives of the "STEAM-6E course of the IoT smart cane creative design" should include three dimensions, STEAM course, 6E instruction, and project knowledge and competence, as well as 17 objectives. Thus, this study guides students to obtain STEAM integrated knowledge, the 6E implementation process, and knowledge and competence related to the IoT smart cane creative design project.

Second, The implementation process of the STEAM-6E instruction, as developed by this study, combines the STEAM learning concepts in a 6E model to practice instructional activities. According to objectives of the course, teachers conducted the course by guiding and helping students to solve problems. It focused on students and established the implementation key points of teachers and students in the different phases of the course to ensure that students can accomplish the tasks of different phases and result in the desired outcome.

Third, After 15 weeks of STEAM-6E project course instruction, most of the health care department students of the vocational and technological college suggested that teachers' explanation and practice course allowed them to comprehend STEAM knowledge, acquire 6E practical experience, and obtain project related IoT techniques, such as the knowledge and competence associated with the smart cane.

Fourth, After 15 weeks of STEAM-6E project course instruction, most of the health care department students of the vocational and technological college suggested that they are satisfied with STEAM course design, 6E instruction process planning, and manufacturing of the teaching materials and tools of project knowledge and competence, such as the IoT techniques and the smart cane.

Finally, After analysis and discussion of students' STEAM-6E learning process, this study realizes that the students were extremely interested in applying IoT new technology to manufacturing a smart cane, which shows that, in this project, students' observation results of the daily live problems of seniors at home can be the base of creative design. It guides students to recognize the development trends and applications of IoT new technology. In this course, the examples of elderly cases and scientific knowledge discussions led to the response of students, and interactions and discussions between teachers and students became part of students' learning.

5.2 Suggestions

First, this study introduces STEAM integrated thoughts in the project course planning of IoT smart cane creative design, which is implemented by 6E instruction. Thus, when developing a STEAM-6E course, teachers should include the contents of multiple subjects. When designing the topics of STEAM courses, they can invite teachers of different subjects to the discussion to establish proper instructional contents and activity processes according to specialty of the topic.

Second, the STEAM-6E course is based on PBL. In the instruction, teachers guide the students to design, manufacture, test, modify, and accomplish the works of different groups. After the course, teachers can instruct students according to their specialty and share the problems encountered by different groups in the creation process. Thus, students can review their design and reflect on the course to obtain knowledge, which triggers their learning motivation and demonstrates the value of project-based instruction.

Acknowledgement

The study was sponsored by K. C. Wang Magna Fund in Ningbo University.

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