修 士 論 文

An Edutainment Robotics System with Online Self-learning

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Abstract

Robotics is an excellent subject for engineering quality education because it combines mechanics, electronics, artificial intelligence, automation and computer science. How to broaden students' thinking, improve students' information literacy, cultivate students' exploration spirit and practical ability, as well as team spirit and innovation spirit in robot education is still a practical problem in robot education. Robot itself is a technology, but what often plays an important role is not the tool itself, but the practice mode and process. Based on the robot courses and creative teaching strategies, combined with the characteristics of virtual robot, and referring to the construction of existing robot education mode, this paper explores the application mode of virtual robot in self-leaning and through some methods to improve students' self-efficacy and learning motivation. We developed this edutainment E-system for practice. In order to evaluate the self-efficacy and learning motivation of students, we conducted evaluations through questionnaires and performance evaluation systems. Then through questionnaire to explore the influence of the platform on leaning effect, and collect feedback about the E-system, so as to provide feedback suggestions for the construction of learning mode, the selection of learning strategies, and the improvement of the edutainment E-system itself.

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Chapter I.

Introduction

1.1 Social Background

In recent years, many researchers have done a lot of research of Robotics. Searching in the ACM Digital Library with "Robot education" as the keyword, from January 2000 to December 2020, a total of 125,102 related records were obtained, and the number of researches has increased year by year. As early as 1991, P McKerrow published a book explaining a lot of robotics related knowledge[1]. M.J. Mataric put forward robotics as a teaching material for all ages in 2004[2]. Robotics is an excellent subject for engineering quality education because it combines mechanics, electronics, artificial intelligence, automation and computer science and so on. Various types of robots have been applied to robotics educational fields. As early as 1994, the Massachusetts Institute of Technology (MIT) established the "learning engineering by designing LEGO robots" course[3], with the purpose of improving the design and creativity of engineering design students and trying to integrate robot education with science experiments.

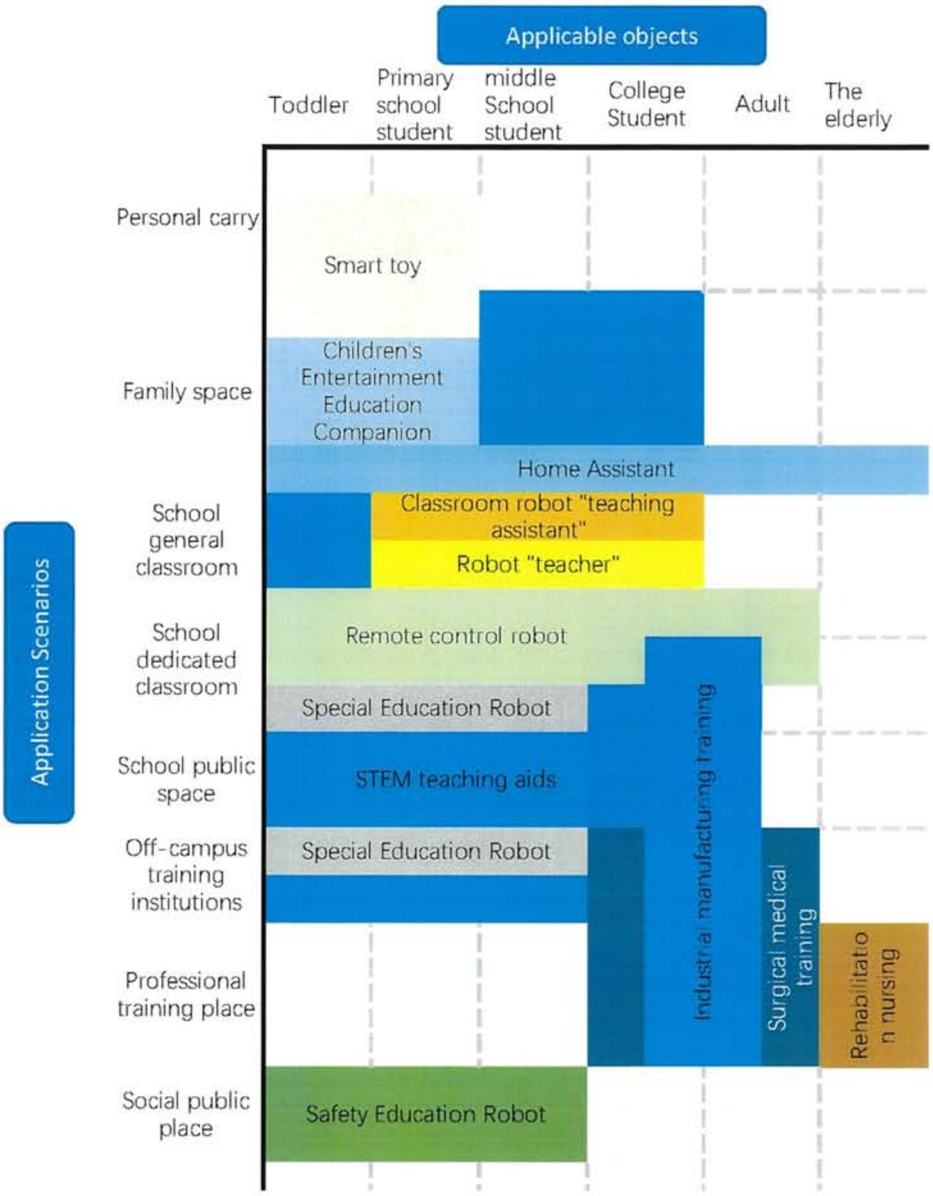


Figure 1. 12 types of educational robot product application scenarios

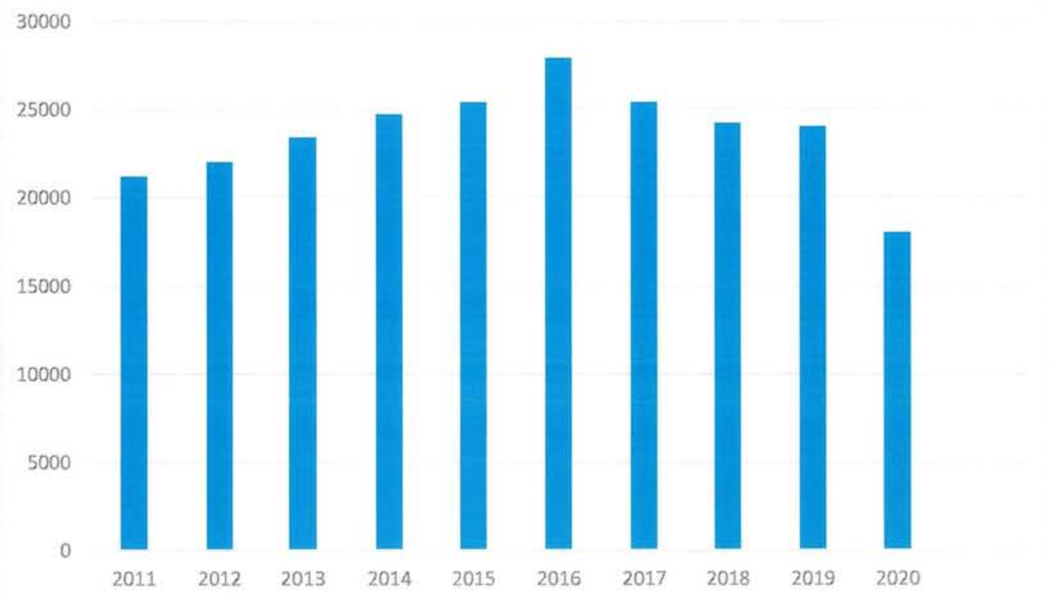
The 2019 Global Educational Robot Development White Paper[4] analyzes the research hotspots of educational robots in the past five years, and proposes two dimensions of "applicable objects" and "application Scenarios" of educational robots, and proposes an analysis framework from the perspective of the relationship between products and users to illustrate the market Development status.

From the perspective of market development status, first of all, educational robot products are mainly used in homes and schools, such as smart toys in the home, children's entertainment and education companions, and home intelligent assistants; remote control robots in general classrooms and dedicated classrooms in schools, STEAM teaching aids; special education robots for autism in dedicated classrooms or training institutions. Secondly, some products are still in the conceptual stage, such as classroom robot "assistants" and robot "teachers". The functional design of these products still needs market verification. Third, educational robot products in public places mainly involve safety education functions. Finally, the development of educational robots in professional training shows the potential of educational robots in various fields, such as industrial manufacturing training, surgical medical training, rehabilitation and nursing care.

According to 2019 Global Educational Robot Development White Paper, there are currently two problems in robotics education: (1) At the level of training institutions, the lack of industry standardization has led to the lack of standardization of robot education products; insufficient supporting facilities have made it difficult to popularize. (2) At the level of the teaching process, there is a lack of scientific planning for courses in the industry, and the commercialization of competition activities is serious.

With the development of information technology, electronic equipment is constantly being updated, mobile Internet is developing rapidly, and various application software are becoming more abundant. The cost of human "digital life" has been reduced year by year. At the same time, information technology is also playing an increasingly important role in students' learning. In 2000, "Educational Technology White Paper" of the US Department of Education, with the title of "E-Learning: Putting a World-Class Education at the Fingertips of All Children", puts forward 5 goals of American national educational technology:(1) all students and teachers will have access to information technology in their classrooms, schools, communities, and homes; (2) all teachers will use technology effectively to help students achieve high academic standards; (3) all students will have technology and information literacy skills; (4) research and evaluation will improve the next generation of technology applications for teaching and learning; and (5) digital content and networked applications will transform teaching and learning[5].

Table 1. Results Found with Keywords of "Robotics" and "Education" in google scholar



When searched with keywords of “robotics” and “education” in google scholar, a total of 227,000 results were found from 2011 to 2020. Over the last 10 years, research on robotics and education has seen continuous growth from 2011 to 2016.

Although the popularization and promotion of robot education has its important value and far-reaching significance, the implementation of robot education is often limited to a small range of interest groups or robot competitions in many schools. Besides, the high price of physical robot toolkit and the lack of school funds seriously affect the popularization of robot education. More seriously, the impact of COVID-19 on robot education cannot be underestimated. Globally, 22 January 2021, there have been 96,267,473 confirmed cases of COVID-19, including 2,082,745 deaths, reported to WHO[6]. As shown in Figure 2, the number of people infected globally has been showing an increasing trend, and many students around the world have also been affected by COVID-19. Due to the influence of COVID-19, schools with robot equipment can even not use these robots for class teaching.

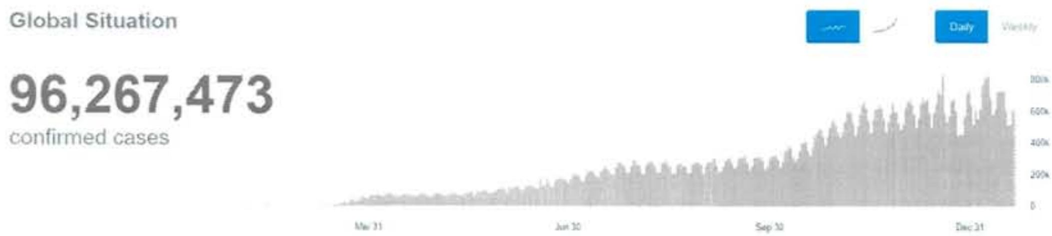


Figure 2. COVID-19 Infection Data

Consequently, the current situation of comprehensive robot education in classroom teaching is not optimistic. The cause of COVID-19 has also brought a lot of inconvenience to classroom practice activities. Therefore, we need to develop a tool that can replace the real robot to carry out learning practice activities.

1.2 Research Purpose

How to broaden students' thinking, improve students' information literacy, cultivate students' exploration spirit and practical ability, as well as team spirit and innovation spirit in robot education is still a practical problem in robot education. Robot is a technology, but what often plays an important role is not the tool itself, but the practice mode and process.

Based on robotics courses and creative teaching strategies, combined with the characteristics of virtual robot, and referring to the construction of existing robot education mode, this paper explores the application mode of virtual robot in self-leaning and through some methods to improve students' self-efficacy and learning motivation. In order to evaluate the self-efficacy and learning motivation of students, we conducted evaluations through questionnaires and performance evaluation systems. Then through questionnaire to explore the influence of the platform on leaning effect, and collect feedback about the E-system, so as to provide feedback suggestions for the construction of learning mode, the selection of learning strategies, and the improvement of the edutainment E-system itself.

1.3 Thesis structure

Chapter 2 describes the mechanical structure and motion generation related to robot, and summarizes the experiments of the previous research. Chapter 3 expounds the relationship between self-efficacy, learning motivation and performance, and provides theoretical support for next research. Chapter 4 presents the system framework of this research and the methods to realize it. Chapter 5 presents the summary and results of the experiment. Chapter 6, as a conclusion, summarizes the research and future topics.

Chapter II.

Robots and Education

2.1 Research Actuality of Robot

In nature and human society, there are a large number of places that humans cannot reach and special occasions that may endanger human life. Examples include mines where disasters occur, disaster prevention and rescue, anti-terrorism struggles, and the surface of extraterrestrial planets. Seeking a feasible way to solve the problem to continuously explore and study these dangerous environments has become the need of the development of science and technology and the progress of human society. Irregular terrain and rugged terrain are common features of these environments, which limits the application of wheeled robots and crawler robots. Previous studies have shown that the wheeled movement method has considerable advantages when driving on relatively flat terrain: the speed of movement is fast, stable, and the structure and control are relatively simple; but when driving on uneven ground, the energy consumption will be greatly increased; and On soft ground or severely rugged terrain, the role of the wheel will also be severely lost, greatly reducing the efficiency of movement. In order to improve the ability of the wheels to adapt to soft and uneven ground, crawler-type movement came into being. However, the mobility of crawler-type robots on uneven ground is still very poor, and the body shakes severely when driving[7]. Compared with wheeled and crawler mobile robots, walking robots have unique superior performance on rugged and uneven roads. Under this background, the research on multi-legged walking robots has flourished[8][9]. The emergence of bionic walking robots shows the advantages of walking robots [10].

Multi-legged robot is a kind of motion mechanism with redundant drive, multiple branches and time-varying topology. It is a special robot that imitates the motion of multi-legged animals. It is a kind of foot-type moving mechanism. The so-called multi-legged generally refers to four-legged and more than four-legged walking robots. Common multi-legged walking robots include quadruped walking robots, hexapod walking robots, and eight-legged walking robots. Since R.B. McGhee, a pioneer of robotics and a famous American roboticist, began to study quadruped walking robots in the 1980s, the research of multi-legged walking robots has been a hot issue and difficult topic for many scholars, and its research status is just like that of Professor J. Angeles point out that the pace of basic theoretical research of walking robot lags far behind its technological development[11].

2.2 Robots in Education

Various types of robots have been applied to educational fields. Basically, there are three different aims in robot edutainment (education with entertainment) [12]. One is to develop knowledge and skill of students through the project-based learning by the development of robots (Learning on Robots). Students can learn basic knowledge on robotics itself by the development of a robot. The next one is to learn the interdisciplinary knowledge on mechanics, electronics, dynamics, biology, and informatics by using robots (Learning through Robots). The last is to apply human-friendly robots instead of personal computers for computer assisted instruction (Learning with Robots). A student learns (together) with a robot. In addition to this, such a robot can be used for supporting teachers by the teaching to students and the monitoring of the learning states of students. An educational partner robot can teach something through interaction with students in daily situation. Furthermore, the robot can observe the state of friendship among students. This is very useful information for teachers, because it is very difficult for a teacher to extract such information from the daily communication with students.

Depending on the teaching content, the needs of teachers & students, and learning activities, robots can play many different roles in the learning process, and the degree of participation of robots in learning tasks is also different. On the one hand, the robot can be used as a learning tool or teaching assistant. At this time, the robot plays a passive role. This especially applies to robotics education, where students will build, create and program robots[13]. On the other hand, the robot can play the role of a co-learner or a learning partner[14]. At this time, the robot has active and spontaneous participation. Even the robot can also appear as a guide[15]. However, it is obvious that technological advancement is necessary for the perception of social robots before robots can play the role of autonomous instructors. All in all, we can define three main categories of robot roles in learning activities: tools, companions or tutors (see Table 2 for examples of some physical robots participating in teaching activities).

Table 2. Example Case Studies Across Different Roles of an Educational Robot

	Tutor	**Peer**	**Tool**
Language	Robot teaching companion support children's early language development[16]	When a student pronounces a word correctly, the robot says well done[19]	A student learns certain phrases in a non-native language by playing a game with a robot[22]

Science	Motivating Children to Learn Arithmetic with an Adaptive Robot Game[17]	The robot and the student collaboratively solve exercises in a science class[20]	Sensors and actuators in the robot enable the students to learn about physics[23]
Technology	Robot tutors can provide more effective and empathic educational experiences for children[18]	The robot plays a happy animation sound when the students successfully program the robot[21]	The students use LEGO Mindstorms NXT to learn about programming[24]

The human-robot co-learning is a kind of Learning with Robots and we have developed various types of robot partners. In order to develop a comprehensive educational platform related to robotics, increase students' opportunities for hands-on operation, and strengthen students' understanding of robotics, first we must design a robot motion simulation platform and design the basic motion mode of the robot.

2.2 Robot Kinematics

There are two ways to represent the positions of robot manipulators and end effectors (hands, tips) of leg mechanisms, one is to use the joint angle and position as they are, and the other is to use XYZ coordinates[25].

To represent the position vector in the three-dimensional space, the position of XYZ$(x\ y\ z)$, the rotation around the X axis, the rotation around the Y axis, and the rotation around the Z axis $(\alpha\ \beta\ \gamma)$ are used. The position vector is

$$(x\ y\ z\ \alpha\ \beta\ \gamma) \tag{1}$$

At a point in three dimensions, when the X-axis component is p, the Y-axis component is q, and the Z-axis component translates by r, the coordinate system changes from (x, y, z) to (x', y', z'), the translational transformation is

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} x+p \\ y+p \\ z+r \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} p \\ q \\ r \end{bmatrix} \tag{2}$$

The translation transformation matrix in which the X axis component of p, the Y axis component of q, and the Z axis component of r is

$$Trans(p\ q\ r) = \begin{bmatrix} p \\ q \\ r \end{bmatrix} \tag{3}$$

When a point on three dimensions rotates about the Z axis by θ, the rotation transformation is

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{4}$$

A rotation transformation matrix that rotates by θ around the Z axis is

$$Rot(Z, \theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{5}$$

Similarly, the rotation transformation matrix that rotates by θ around the X-axis the Y-axis are respectively

$$Rot(X, \theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \tag{6}$$

$$Rot(Y, \theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \tag{7}$$

A homogeneous transformation matrix is used to represent the translation operation and the rotation operation in the same format. By using the homogeneous transformation matrix, all can be expressed in a unified manner (by multiplication) in the form of linear transformation. In general, the homogeneous transformation matrix from the coordinate system $\sum_i$ to $\sum_{i+1}$ is

$$^{i}T_{i+1} = Trans(l_{xi}, l_{yi}, l_{zi}) \cdot Rot(a, \theta_{i+1}) \tag{8}$$

l_i represents the translational movement amount of joint $i + 1$, a represents the rotation axis of joint $i + 1$, θ_{i+1} represents the displacement angle of joint $i + 1$, R represents the rotation transformation matrix, and P represents the transformation matrix.

The transformation matrix and the rotation transformation matrix on the X, Y, and Z axes are respectively,

$$Trans(p, q, r) = \begin{bmatrix} 1 & 0 & 0 & p \\ 0 & 1 & 0 & q \\ 0 & 0 & 1 & r \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{9}$$

$$Rot(X, \theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{10}$$

$$Rot(Y, \theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{11}$$

$$Rot(Z, \theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{12}$$

2.3 Virtual Six-Legged Locomotion Robot & Locomotion Creation

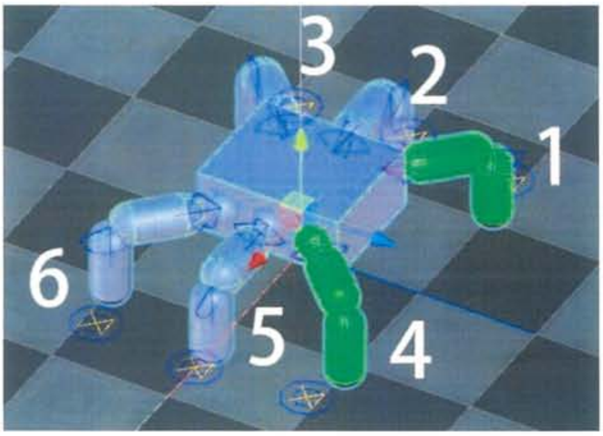


Figure 3. Virtual 6-legged Locomotion Robot

As shown in Figure 3, for the robot used in this study, we designed a six-legged walking robot with three links, three joints, and three degrees of freedom in consideration of the stability of the walking motion of the robot. The numbers 1 to 6 are the leg numbers. Basically, we need to set 18 joint angles to make a posture in the locomotion. The color of 1st and 4th parts of the robot is different from others for user to know the moving direction. The parameters of this robot are based on the actual machine experiment using the robot kit Bioloid manufactured by ROBOTIS[26], and some parameters such as joint angle limitation, mass, and torque are based on the parameters of Bioloid parts[27].

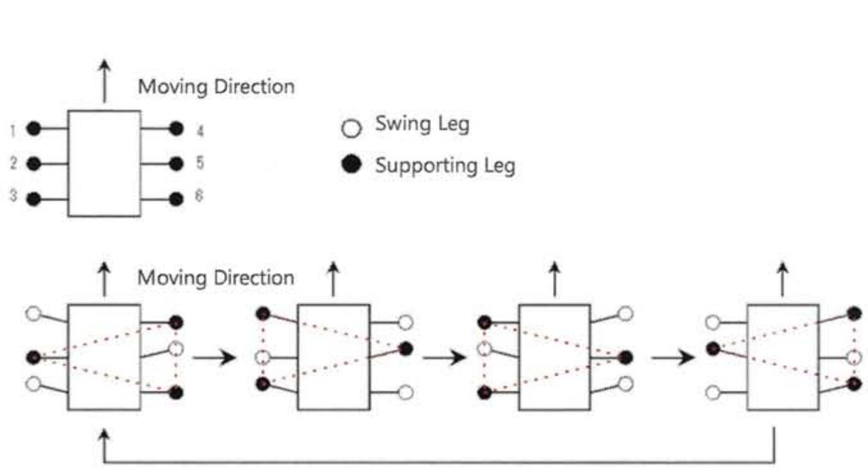


Figure 4. Simple diagram of tripod gait

We proposed several types of robot gaits. First, as shown in Figure 4, among the six legs, the feet numbered 1, 3, 5 and 2, 4, 6 are divided into two groups, and the same group of feet will be raised and lowered at the same time during exercise. By alternately touching the ground while keeping the tips of the two pairs of legs in the same triangle, stable and simple static walking can be achieved. By applying a tripod gait, a pair of two joint angles can be created, and the generation of joint angles is usually 6 degrees of freedom for 6 legs, but it can be simplified to finding 6 degrees of freedom for a bipod[27].

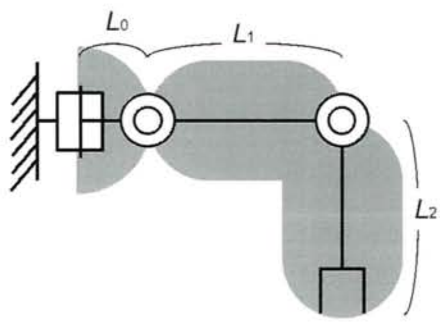


Figure 5. Kinematic Robot Leg Model

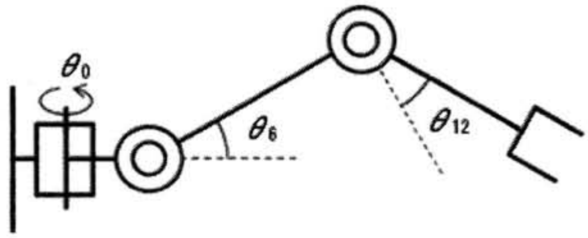


Figure 6. Around the Axis

Kinematic model of the robot's leg is shown in Figure 5. The initial posture (every joint angle is 0°) is shown in Figure 3. The structure of each leg is the same with others. In Figure 6, the link length of the leg L_0 is 15[mm], 1st link L_1 and 2nd link L_2 are 70[mm], respectively. Each joint is assigned its corresponding identification number. Figure 6 shows an example where θ_0 is set 0°, θ_6 is set 30°, and θ_{12} is set 30°. The movable range is between -150° and +150°.

2.4 Previous Research of Multi-Legged Robot Workshop

With the aim of popularizing robot education, our laboratory regularly holds multi-legged locomotion robot design & contest workshop for students who were interested in every year. But it is impossible to hold offline workshop as in previous years due to the COVID-19. Holding online robot workshop is a very good way to help students learn robotics.

This workshop provides the participants with the practice on the design of locomotion patterns for multi-legged robots using ODE (Open Dynamics Engine) [28] from the viewpoint of Learning through Robots. Basically, participants don't need the programming skill, but we assumed that participants install ODE on Windows, Macintosh or UNIX PC beforehand. First, participants learn the basic mathematical formulation of robot geometry and kinematics by trigonometric functions. Next, participants understand how to conduct multi-legged locomotion by computer simulations with ODE, and design locomotion patterns by text files as a group work. Finally, participants join Othello Contest and flag strike robot contest.

2.4.1 Othello Contest

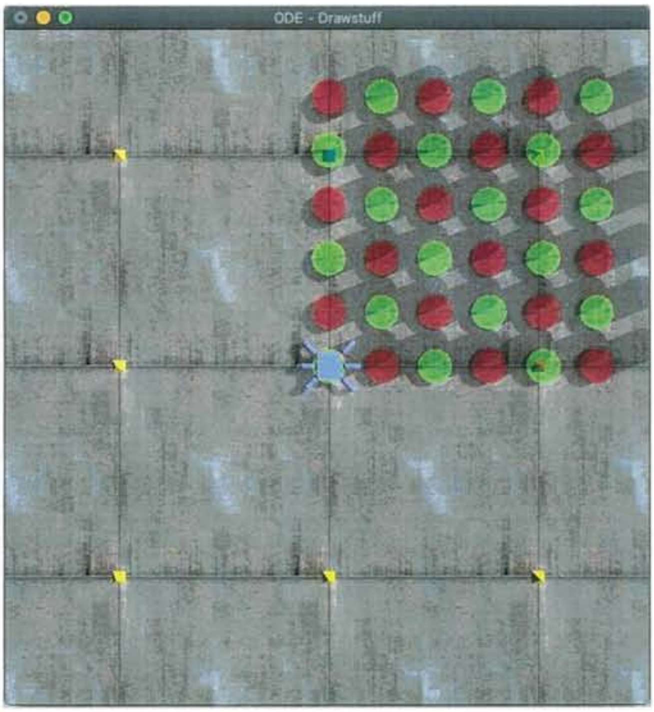


Figure 7. Othello Contest

Othello Game rule:

1. Othello field is consists of 6x6 circular cells.
2. Time limit is 3 minutes.
3. The starting point is one robot left and the other robot in the right.
4. When your robot passes through the color of your cell and the color of your opponent's color, the cell is reversed and becomes your cell.

5. The robot can walk and flip on the opponent's colored disc vertically and horizontally.
6. The score is calculated from the number of discs you have.
7. The winner is the one who gets more discs at the end of time.
8. In the event of an unexpected event, the referee will consult and make a decision.

2.4.2 Flag-Strike Contest

Figure 8. Flag-Strike Contest

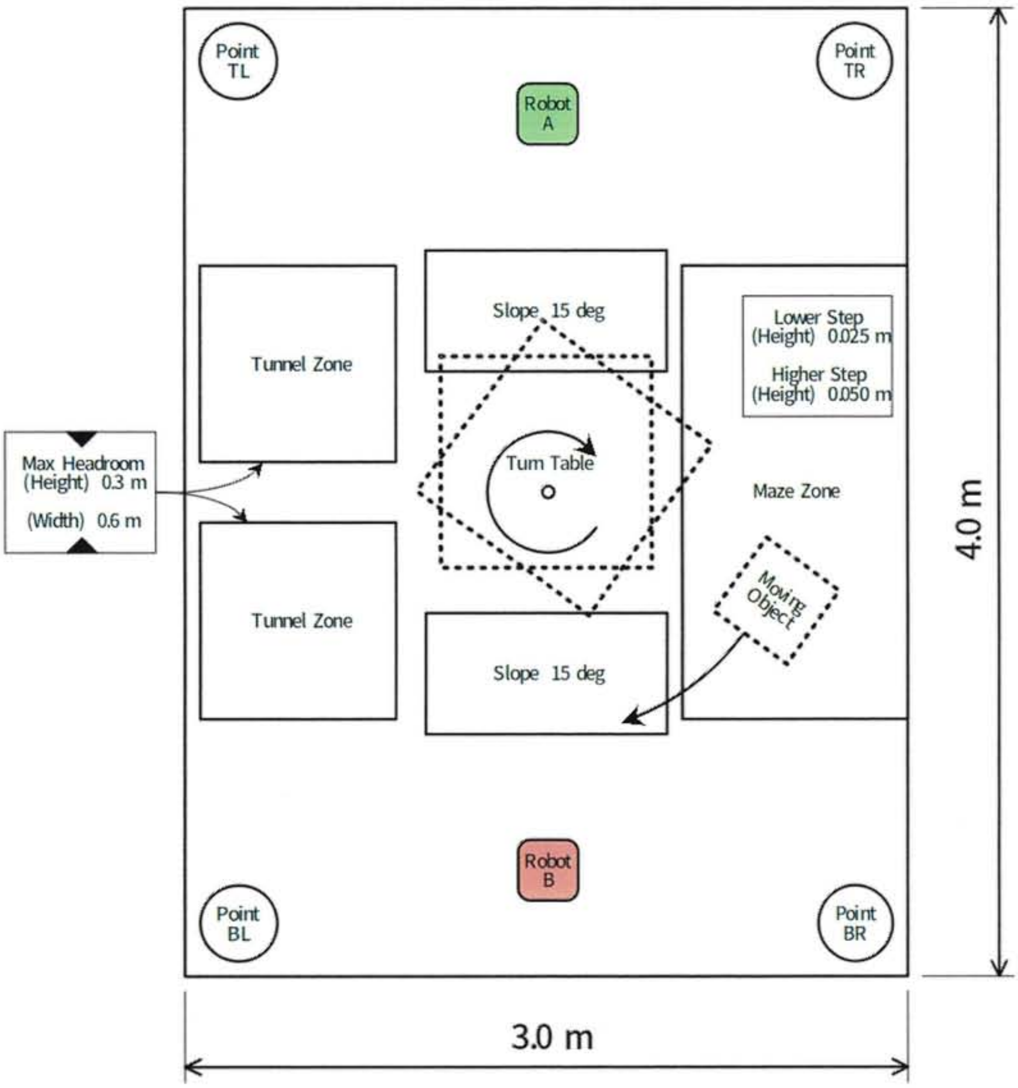


Figure 9. Flag-strike Scene

Flag-strike Game rule:

1. Time limit is 3 minutes.
2. When the center of the robot body enters the point position at the four corners, the color changes and it means that you have taken points. However, the other robot can regain the same point position.

3. Even within the time limit, the match ends when any of the robots has acquired all four-point positions at the four corners.
4. The score of the flag that taken by your robot becomes your score until the end of the match.
5. There are 20 flags with different point in each color.
6. The score is calculated from the number of points you have.
7. The winner is the one who gets more points at the end of time.
8. In the event of an unexpected event, the referee will consult and make a decision.

2.4.3 Workshop 1 - CIS Online Summer School

We provide compiling environment installation instructions of Windows/ Linux/ MacOS for participants in the workshop. In order to reduce the workload of participants, we also provide a packaged virtual compilation environment for participants to use directly. Participants need to use the compilation environment to compile their robots after installing the compilation environment. Participants will learn how to adjust the robot's behavior in this process, and use their adjusted robots to participate in the competition.

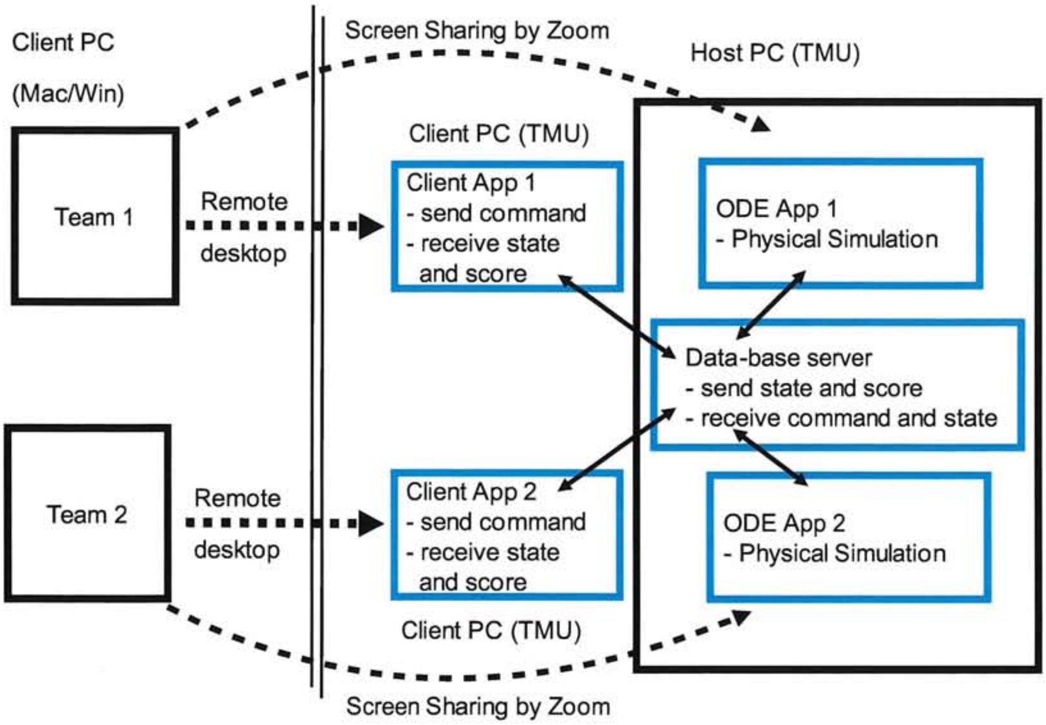


Figure 10. System Architecture for CIS Contest

In order to realize the remote control of the robot by the contestants, we achieve the goal through the cooperative use of TCP-IP communication, UDP communication and remote desktop software. The system network architecture is shown in Figure 10. Specifically, to complete a competition, the following steps are required:

1. In the Kubota Lab, PC 1 opens the local UDP server and opens two robot programs
2. In the Kubota Lab, PC 2 and PC 3 each open a robot control program
3. Share the robot screen of PC1 with the two contestants through Zoom
4. Participants A and B connect to PC 2 and PC 3 through remote desktop software (such as TeamViewer) respectively

5. Participants control the robot control programs opened on PC2 and PC3 respectively, and simultaneously observe the game screen shared by Zoom to complete the game

The remote control interface is shown in Figure 11. From top to bottom is the score of the game, the remaining contest time and the team information.

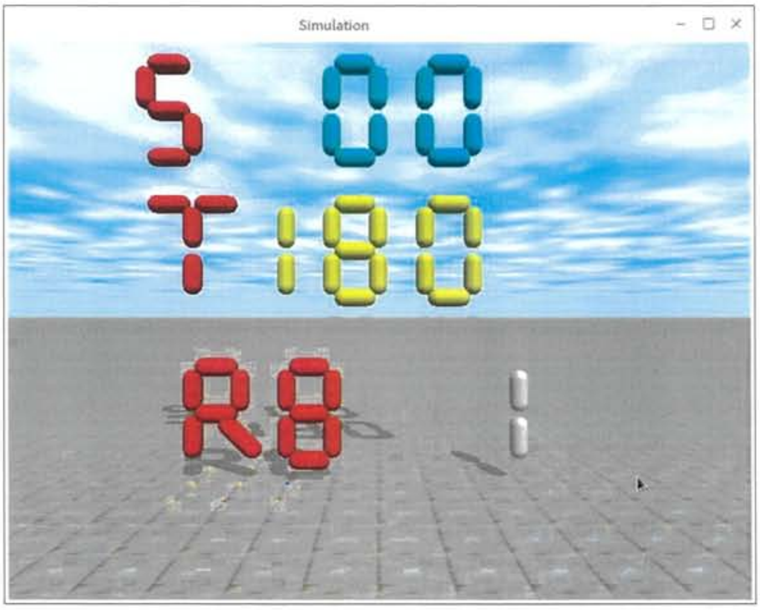


Figure 11. Remote Controller

Although this architecture makes it possible for competitors to participate in competitions remotely, there are still many problems.

Problems in CIS Workshop:

1. Although we provide installation instructions for the compilation environment under different platforms, in actual remote operation, various difficult-to-solve problems will be encountered due to the complexity of the environment, and it will take a lot of time to build the environment.

2. The system architecture is complex, and the actual running of the software will encounter various troubles. The server side needs at least two people to perform auxiliary work.
3. The remote control software operation is not intuitive and will cause interference to the contestants.

2.4.3 Workshop 2 - Locomotion Artificial Creatures Online Contest (LACOC)

In view of the problems encountered in CIS summer school, we simplified the system structure, and the simplified system structure is shown in Figure 12. First of all, we only provide the virtual machine image file of the packaged compilation environment, and provide all the files and instructions needed for the competition in the image file. Then, we use VPS with public IP to build the server, adjust the server and robot program, so that the original local network service can run under the public network.

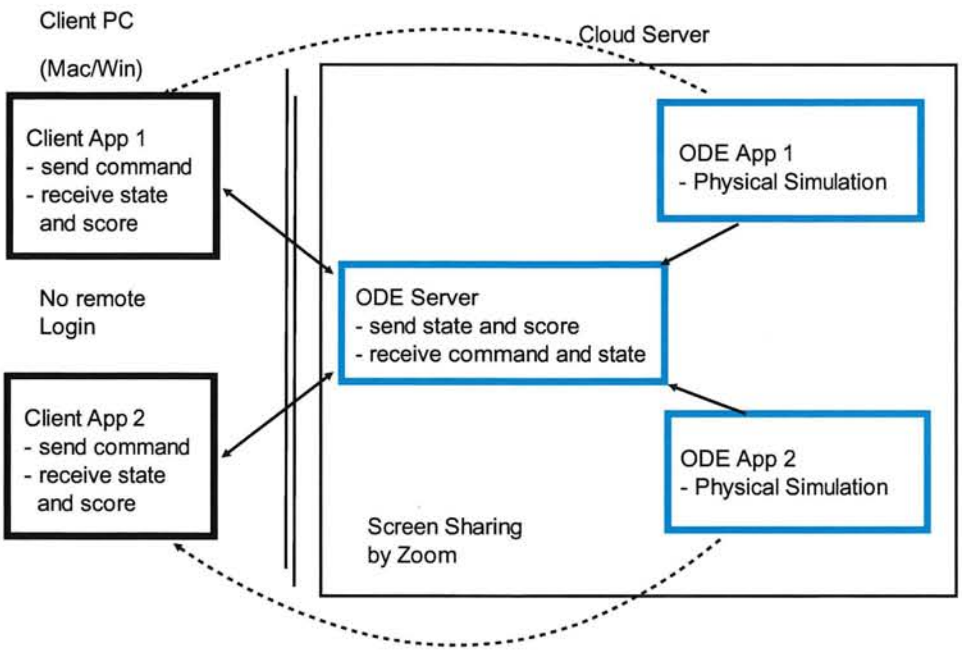


Figure 12. System Architecture for LACOC

The actual test in the Kubota laboratory is shown in Figure 13. Beside the original operation interface, in order to provide a more intuitive control interface, the new design of the control interface is shown in Figure 14.

Figure 13. Real Machine Test

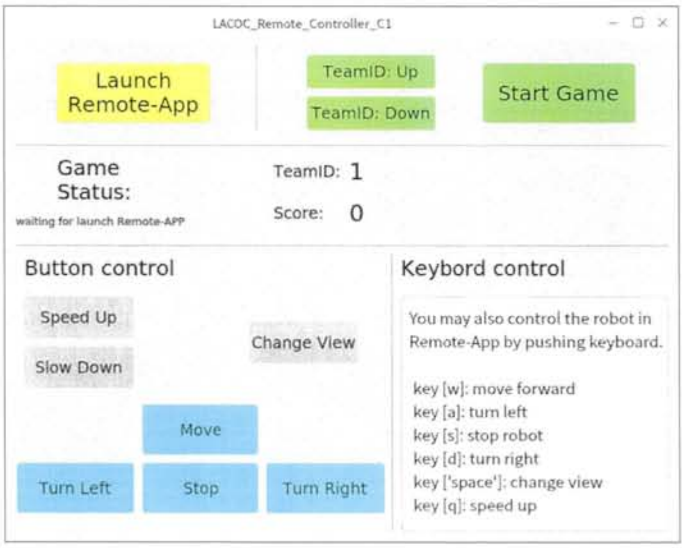


Figure 14. LACOC Controller

Under this system framework, it has the following advantages:

1. Simplified the construction of the compile environment of the contestants
2. Participants no longer need remote control software, using the control program in the virtual machine, they can directly control the robot remotely

To complete a competition, the following steps are required:

1. Start global UDP server in VPS and start two robot programs
2. Share the robot image of VPS with two competitors through zoom
3. Contestants A and B open control program 1 and 2 in the virtual machine respectively
4. Participants operate control program 1 and 2 respectively, and watch the game screen shared by zoom synchronously to complete the game

Although some of the problems in CIS Summer School have been solved, this structure also brings some new problems:

1. There are many programs when running the server and robot simulation program at the same, which will lead to serious stuck in hosting the contest
2. It is inconvenient that the server program needs to be manually restarted by administrator every contest round
3. The separation of the operation interface and the actual running robot program caused a lot of trouble to the contestants

Chapter III.

Self-efficacy, Motivation, and Performance

Students are the main part of learning activities. Just as a person has his/her motivation and purpose for doing anything, students learning by participating in learning activities also have his learning motivation and purpose. Learning motivation is mainly the student's self-consciousness in learning and his strong interest in learning, which stimulates the internal process or mental state of students in learning activities to make their behaviors develop normally toward a certain learning goal. The proper learning motivation is a necessary condition for mastering knowledge, therefore, it is necessary to fully mobilize students' learning enthusiasm, and correctly cultivate and stimulate students' learning motivation.

3.1 3 Learning Elements

Figure 15. 3 Elements of Learning

Learning motivation, learning will and self ability are the basic elements of learners' characteristics which are shown in Figure 15, which play an important role in learning activities. Especially in E-learning, where learners need to control the learning process independently, it is more important. Learning motivation, as a way to help students overcome external interference and improve their learning willpower to promote learning, has become an important correlation research of educational theory and practice. It mainly relies on some behavior control strategies to overcome the decline of learning motivation and the generation of negative learning emotions. The separation of teachers and students and the separation of teaching in e-learning make it more important to improve students' learning motivation.

Since learning motivation has a wide range of influences on the learning process, this influence will eventually manifest in the learning results. The relationship between learning motivation and learning results has always been a concern of psychologists and educational practitioners. It is very important for educators to correctly grasp the relationship between the two. The influence of learning motivation on the learning effect can be divided into two aspects: one is the influence of the overall motivation level on the whole learning activity; the other is the influence of learning motivation on the learning effect in specific learning activities.

In general, the stronger the learning motivation, the higher the students' enthusiasm for learning activities, and the better the learning effect. As a kind of non-cognitive factor, learning motivation does not directly affect the learning effect, but only through the intermediate link of the student's learning behavior. In addition to being affected by learning motivation, learning behavior is also affected by a series of subjective and objective factors. Therefore, learning motivation is only one of the factors that affect the results of learning, rather than a sufficient condition; in addition to motivation, there are factors that affect learning. Students' intelligence, knowledge base, learning methods, personality characteristics, physical and emotional status, etc. Generally speaking, learning motivation, as a non-intellectual factor, will directly promote learning. However, it cannot be considered that learning motivation and learning results are a one-way influence relationship. Motivation is not absolutely a prerequisite for learning. There is an obvious mutual causal relationship between it and learning. American educational psychologist D.P. Ausubel clearly pointed out that the relationship between motivation and learning is a typical complementary relationship, not a one-way relationship[29]. The result of successful learning, on the one hand, is the acquisition and mastery of knowledge and skills; on the other hand, it is the desire for knowledge, self-esteem, praise from others, and so on. It also urges people to regard further learning to obtain a higher degree of satisfaction as a new and urgent need, thus producing strong learning motivation. Therefore, it is not necessary for teachers to delay learning activities before students show proper interest or motivation in learning. For those who have no learning motivation, especially the younger students, the best way of teaching is to focus on the cognitive aspect of learning rather than the motivation aspect, and to effectively teach them to master the relevant knowledge, so that they can have a successful experience. When students taste the pleasure of learning, they may have the motivation to learn.

3.2 Self-efficacy

Over the past few decades, students' motivation to learn, to actively participate in learning, and to learn independently and/or in a classroom under difficult circumstances has been a topic of concern to academics and educators at all school levels, nationally and internationally[30].

Albert Bandura, a pioneer humanist and father of the concept of self-efficacy, defined it as "people's beliefs about their capabilities to produce designated levels of performance that exercise their influence over events that affect their lives" [31].

Self-efficacy determines how we think and feel about ourselves. For example, imagine someone who aspires to become a doctor but is not sure about his medical and academic potentials. He puts in all the effort and does his very best, but at the end of the day, he is unhappy as he lacks confidence in himself. What this person requires is self-efficacy – a strong sense of trust in himself. Self-efficacy in all forms influence our thoughts, emotions, actions, and motivation. It operates mainly through the cognitive and affective channels and plays a crucial role in shaping our perception of life experiences. Bandura believed that we build a self-system based on our social skills, cognitive skills, observational learnings, and social backgrounds. This self-system is the backbone of our personality and self-efficacy is one of the essential components of it. A person's self-efficacy is different in different fields. Therefore, there is no general sense of self-efficacy. Whenever discussing self-efficacy, it refers to the sense of self-efficacy associated with a particular field.

The factors that affect the formation of self-efficacy are listed in Table 3.

Table 3. Factors of self-efficacy

Factors	Explanation
Direct Experiences	This source of efficacy information has the greatest impact on self-efficacy. Generally speaking, successful experience will increase performance expectations, and

	repeated failures will reduce performance expectations.
Vicarious Experiences	Many people's efficacy expectations are derived from the alternative experience of observing others. A key here is the consistency between the observer and the role model, that is, the situation of the role model is very similar to the observer.
Verbal Persuasion	The value of verbal persuasion depends on whether it is practical or not. Verbal persuasion lacking a factual basis has little effect on self-efficacy. Persuasion based on direct experience or alternative experience will be more effective.
Emotion Arise	People can expect success when they are not bothered by disgusting stimuli. However, the individual's psychological and physical reactions and strong emotions when facing a certain activity task usually hinder behavior and reduce self-efficacy.

Self-efficacy has the following functions: Determine people's choice of activities and persistence to the activity; Influence people's attitudes in the face of difficulties; Influence the acquisition of new behaviors and the performance of learned behaviors; Influencing activities during activities mood. As shown in Figure 16, Self-efficacy refers to the sense of ability and trust to oneself based on the relationship between the outcome expectation that one's actions will produce results and the efficacy expectation that it can be successfully completed.

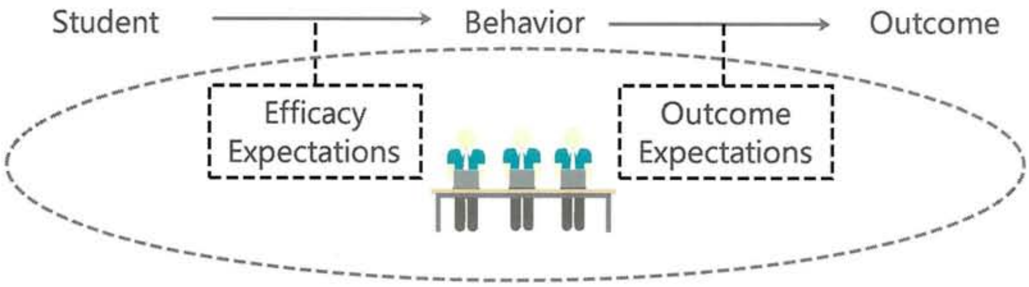


Figure 16. Relationship between efficacy expectations and outcome expectation

Self-efficacy affects or determines people's choice of behavior, as well as the degree of persistence and effort to the behavior; affects people's thinking patterns and emotional response patterns, and then affects the acquisition of new behaviors and the performance of learning behaviors.

1. People with a high sense of self-efficacy: high expectations, showing achievements, handling things wisely, willing to meet the challenges of emergencies, able to control self-defeating thoughts-able to use wisdom and skills when needed.
2. People with low self-efficacy: cringe, show failure, deal with problems emotionally, helpless in the face of pressure, easily disturbed by fear, panic and shyness-their knowledge and skills cannot be used when needed.

From Toshie Wada's research on the relationship between self-efficacy and academic performance[32], Tasashi Shibayama's research on self-efficacy and motivation to learn[33], Maeda research on the effect of self-efficacy on learning behavior based on Japanese Kanji learning can be considered that appropriate feedback on learning behavior through others' evaluation and self-evaluation can improve self-efficacy[34]. In addition, by improving self-efficacy, it can be expected that the learning motivation will be improved, and learners will have a strong interest in learning and intellectual curiosity, and will participate in learning voluntarily and patiently.

3.3 Motivation

Dale H. Schunk pointed out that expectation of outcomes or beliefs about possible outcomes of actions is important because people strive for positive outcomes, and expectation of outcomes and self-efficacy are often related. Efficient learners expect and usually obtain positive results for their actions[35].

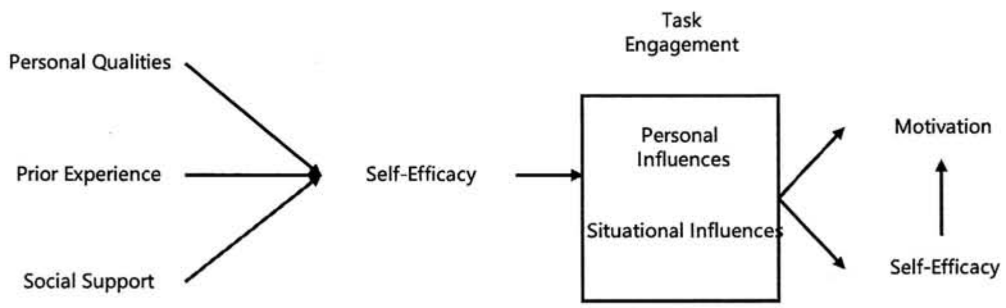


Figure 17. Model of achievement behavior highlighting the role of self-efficacy

Individuals differ in their self-efficacy for learning or performing actions as a function of their prior experience at the same or similar activities and such personal qualities as abilities and attitudes. Initial self-efficacy also is affected by the type of support persons receive from significant individuals in their environment[35]. The role of self-efficacy in behavioral change is highlighted in the model shown in Figure 17.

The evidence also shows that both self-efficacy and motivation beliefs contribute significantly to the level of performance[36]-[38]. Both of self-efficacy and motivation are needed for academic success, and the self-efficacy of students alone will not insure success if the motivation is not there. It seems that self-efficacy is associated with motivation, which in turn, enhances the academic performance of the students. Therefore, it can be suggested that motivation in learning reflects a means for activating students' ability of academic achievement.

Cultivating and motivating students' learning motivation can be specifically considered from the following aspects[39].

Cultivation of Learning Motivation:

1. Understand and meet the needs of students, and promote the generation of learning motivation
2. Pay attention to cultivating students' achievement motivation and make students' learning motivation lasting
3. Cultivate students' attribution view of success due to hard work
4. Cultivate students' interest in understanding

Stimulation of Learning Motivation:

1. Help students set clear and appropriate learning goals
2. Create questioning situations and adopt heuristic teaching to stimulate students' cognitive curiosity
3. Adopt novel and diversified teaching methods to stimulate students' learning motivation
4. Carry out competition education for students, properly carry out learning competition, and encourage students' enterprising spirit
5. Establish an information feedback mechanism to stimulate students' learning motivation

Chapter IV.

Robotics Edutainment E-System

Our goal is to design an edutainment E-system for robot courses, which is suitable for robot teaching of different academic levels. This thesis provides guidelines for defining the concepts used in the proposed standard robotics curriculum. As mentioned above, the system should be flexible, meet the conditions of easy or rapid deployment, and be suitable for a variety of different types of robot design, which can be adjusted according to the different educational environment. We think this is an important set of guiding principles, because it solves some shortcomings of the existing robot courses. Using virtual robot to adapt to different teaching tasks, the design principles of this edutainment E-system should meet the following principles:

1. Students don't need to pay attention to specific hardware or software platform, this E-system should be able to provide learning objectives and learning module examples of different kinds of robot concepts
2. In order to help students understand robotics effectively, a comprehensive learning framework is needed
3. Provide flexibility across academic level or robotics experience.

4.1 Robotics Edutainment E-System Architecture

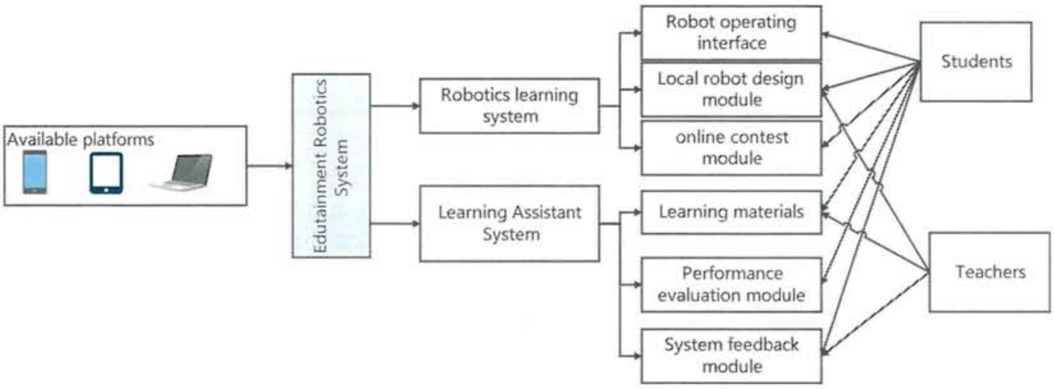


Figure 18. Robotics Edutainment E-System Architecture

This robotics edutainment E-system is a E-learning system based on computer virtualization and Internet technology. First, computer virtualization technology is used to build a robot simulation platform, and then it uses Internet technology to support and expand students' learning. It will not Replace the traditional education methods, but will greatly improve the efficiency of education. Since E-learning has many advantages such as flexibility, diversity, measurement, and openness in time and space, it will become a popular way of learning in the new century as shown in Figure 18. Students use each module in the system to complete self-study tasks. Teachers can update or add different types of robots and textbooks to the system regularly, and adjust subsequent teaching content by consulting students' feedback.

In the traditional E-learning mode, teachers teach students regularly according to teaching tasks. Students participate in Online Autonomous Learning and cooperative learning courses, or complete the teacher's homework. But in my thesis, we want to strengthen the communication between teachers and students, students and students. Teachers can encourage students to cooperate with each other to complete simple learning tasks or complex group projects. When students study each unit, they can learn independently online, complete the test through the network, and make statistics on the test results. Through cooperative learning, students can not only acquire knowledge, but also cultivate team spirit and coordination ability, improve the skills of dealing with people, and enhance their ability to express themselves. Figure 19 provides the interaction pattern for the proposed architecture.

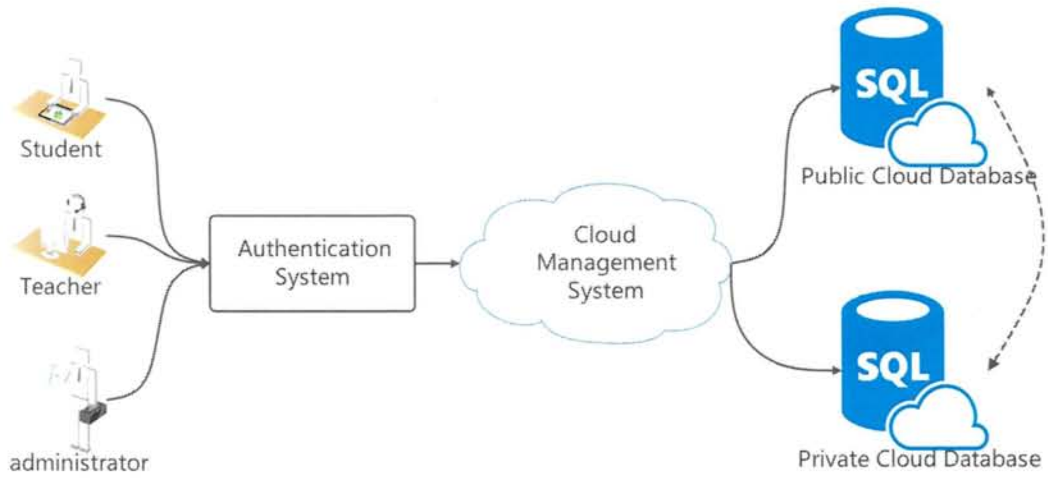


Figure 19. Architecture of Interactive mode

Teachers can use this system to control each part of the teaching content. Students can also make their own learning plans and decide their own learning methods through the e-system. Through reasonable task planning, gradually guide those students who don't know much about robots to achieve their final goal step by step, so that those students in different stages can more smoothly enter the next goal. And this process is also gradually from the teacher to guide students to learn into students' spontaneous learning of relevant knowledge. The process is shown in Figure 20.

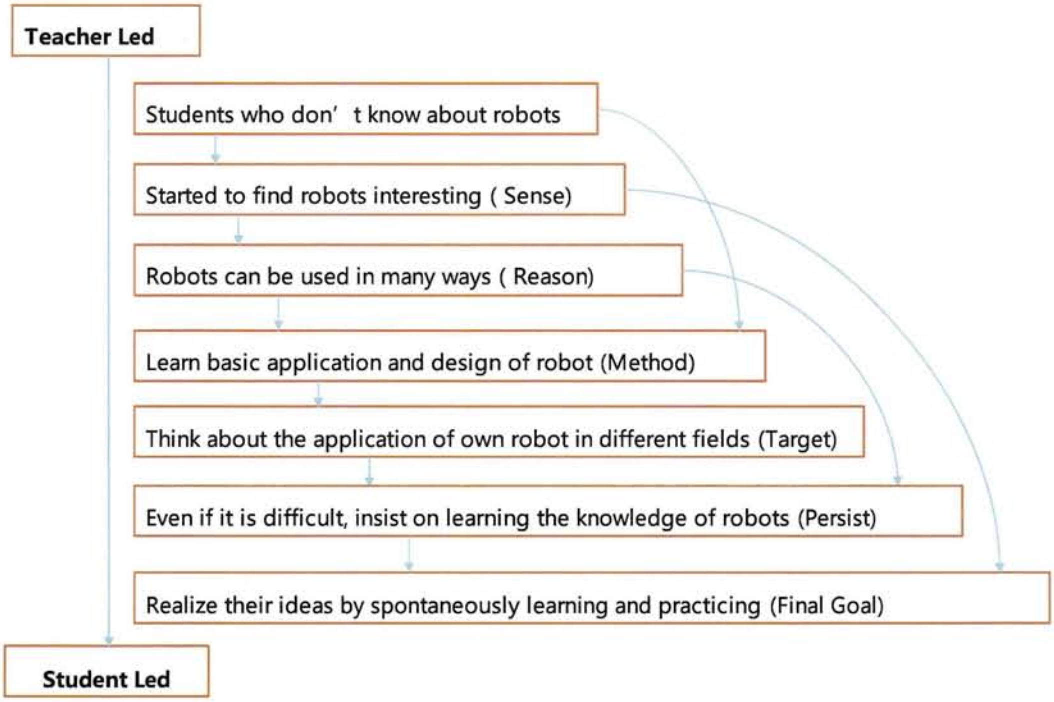


Figure 20. Different Stages of Learning

4.2 Robot Simulation Application

Unity is a cross-platform 2D/3D game engine developed by Unity Technologies[40]. It can be used to develop games for mobile devices such as Windows, MacOS, Linux, iOS and Android. Unity provides physics engine in Project to ensure that the objects correctly accelerate and respond to collisions, gravity, and various other forces[41]. Therefore, the robot education system can take advantage of the Unity engine's advantages in physical simulation to provide users with a high-quality robot simulation platform, and implement a complete distance education system by extending the platform.

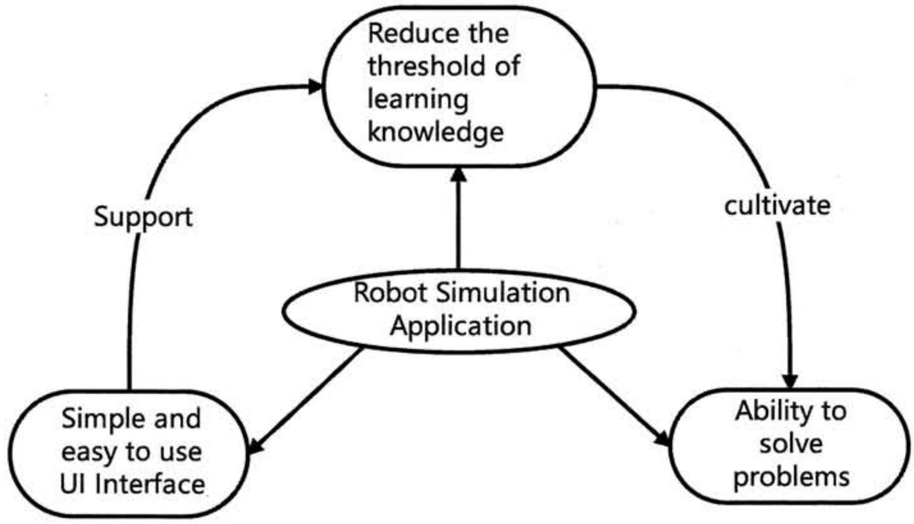


Figure 21. Properties of virtual robot software.

In addition to being a teaching aid software, virtual robot software is also produced to simulate certain functions of physical robots. Therefore, virtual robots also have the properties of its' own shown in Figure 21. In the case that physical robots cannot be used, virtual robots are used instead of physical robots to complete the teaching of robot-related knowledge and the cultivation of relevant abilities of students. Virtual robot software needs to be solved to complete three parts including software operating environment, knowledge learning and problem solving.

The software operating environment refers to the robot construction and strategy design platform integrated in the virtual robot, as well as the operating environment. Teachers and students need to learn and use the software platform's operating specifications, usage methods, and editing skills. The software needs to provide a simple and easy-to-use visual UI Interface to make editing operations easy to learn and reduce the threshold of learning knowledge.

Knowledge learning includes robot knowledge, physics knowledge, programming knowledge, etc. Virtual robots provide many drive devices with their own physical attributes to help students of different levels learn relevant knowledge, while reducing the impact of complex natural physical environments on equipment and implementation effects, and reducing the difficulty of knowledge learning; providing a visual robot parameter control system, Make the way to modify the robot's motion parameters simple and easy to learn, and cultivate students' procedural thinking and mathematical logic skills.

Problem solving refers to the ability to continuously modify the strategy and run tests in order to improve the functions of the robot and solve the actual tasks. The virtual robot provides a 3D interactive platform that can carry out scene design, robot construction, robot behavior strategy design, motion simulation and debugging. With the support of these modules, learners can complete tasks constantly revising and perfecting the plan in the process, so that their ability to solve problems can be improved.

4.2.1 Virtual Robot Design

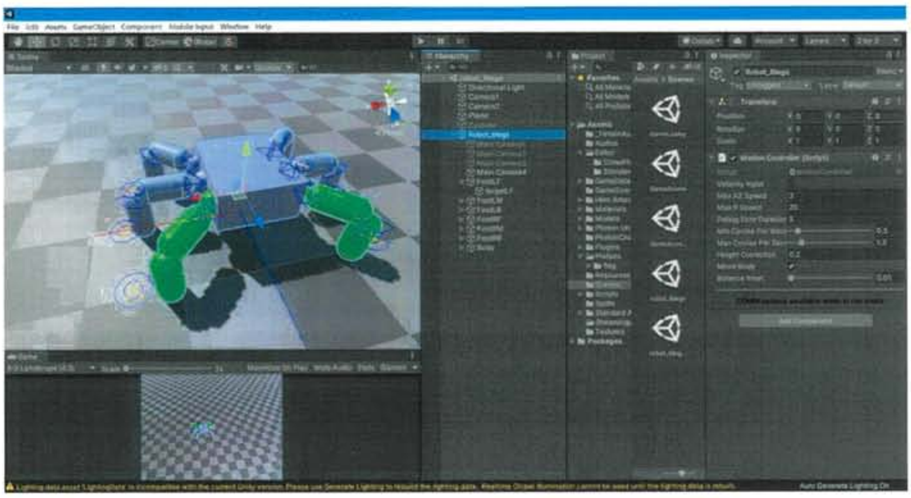


Figure 22. Virtual Robot Design

As shown in Figure 22, the prototype 6-legged locomotion robot is modeled by Unity. the prototype 6-legged locomotion robot is modeled by Unity. The components and joints of the robot body are modeled according to the hierarchical relationship between the parent and the child, and the corresponding attributes such as gravity and friction are set. The joint control script is loaded to the corresponding joint position to realize the motion control of the six legged robot.

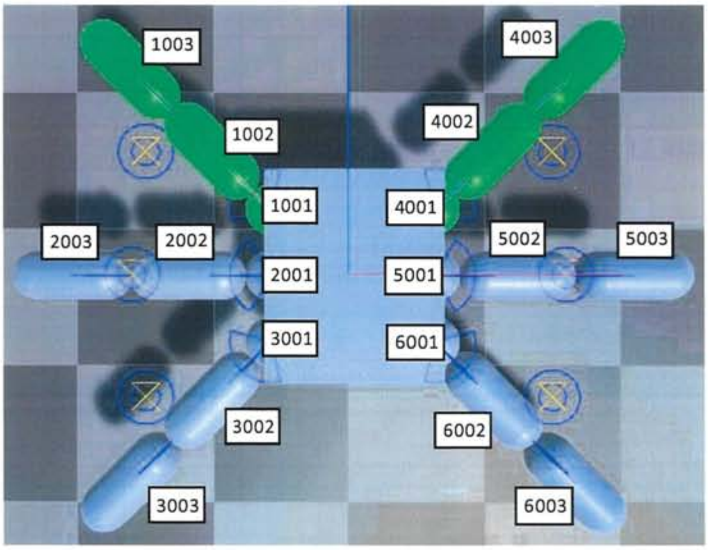


Figure 23. Robot joint number

In order to facilitate the setting of robot joint related parameters, the joint number starts from 1001 and ends at 6003, as shown in Figure 23. The minimum and maximum initial rotation angles of the joint are shown in Table 4. In order to set the initialization angle conveniently, the user can adjust the gait of the robot by modifying the provided parameters txt configuration file without installing Unity.

Table 4. Initialization Angle

joint ID	min Ang	max Ang	pos Ang
1001	-60	60	0
1002	-45	45	0
1003	-30	75	0
2001	-60	60	0
2002	-45	45	0
2003	-30	75	0
3001	-60	60	0
3002	-45	45	0
3003	-30	75	0
4001	-60	60	0
4002	-45	45	0
4003	-30	75	0
5001	-60	60	0
5002	-45	45	0
5003	-30	75	0
6001	-60	60	0
6002	-45	45	0
6003	-30	75	0

4.2.2 UI Interface

As shown in Figure 24, for the convenience of users, the UI is adapted for the mobile terminal. The W|A|S|D|Q|E button in the lower right corner controls the robot to move and turn in different directions. The 1234 button is used to switch different perspectives of the robot. The setting in the lower left corner can call the robot gait editing settings in the interface. As shown in Figure 25 and Figure 26, various parameters of the robot can be set directly through the slider.

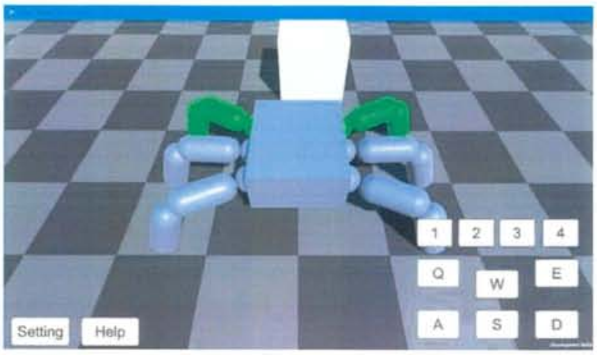


Figure 24. UI Interface 1

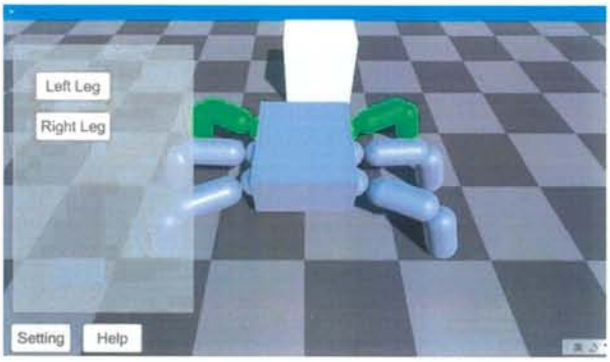


Figure 25. UI Interface 2

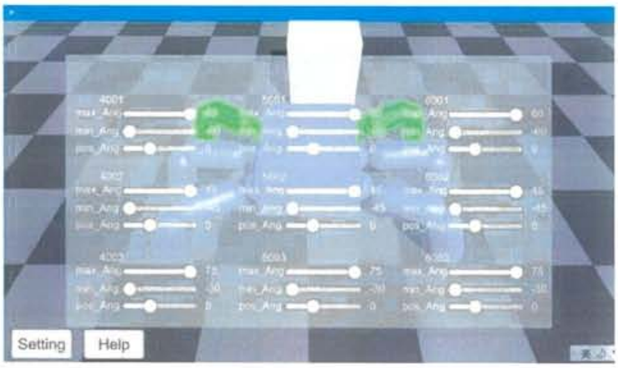


Figure 26. UI Interface 3

If users press the help button on the left, the system will jump to our robot learning web page(https://sites.google.com/view/lacoc-test/home). Students can easily access our website through the help system in the robot simulation application, and they can easily inquire about the leaning materials, questionnaires and other content we provide in the web pages. Figure 27 is the web page we built to help students learn by themselves. Although the current leaning materials is not complete, but the entire system has begun to take shape. It saves the time for students to search in the network, and greatly facilitates the needs of students' autonomous learning.

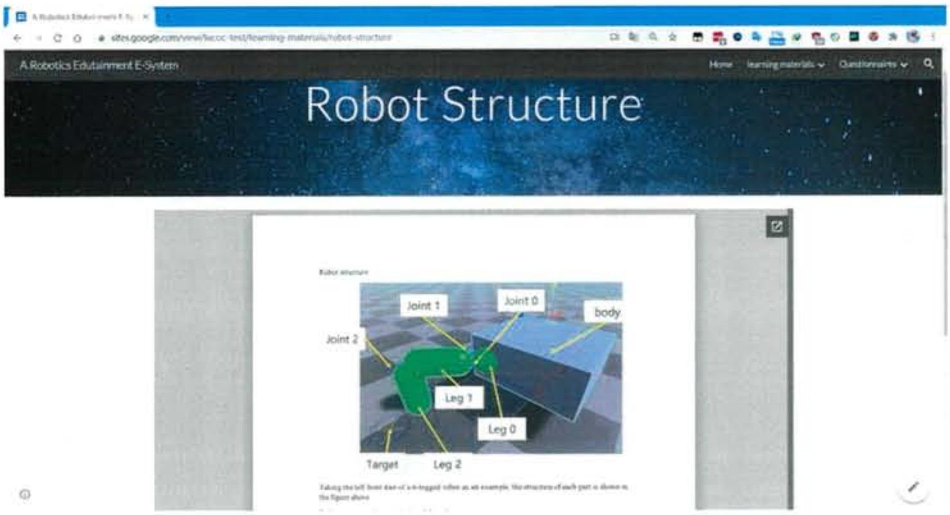


Figure 27. Robotics Edutainment Webpage

4.2.3 Online Contest System

According to the motivation cultivation method mentioned in 3.3, one of them is to hold competitions, so we have added the online contest system shown in this part.

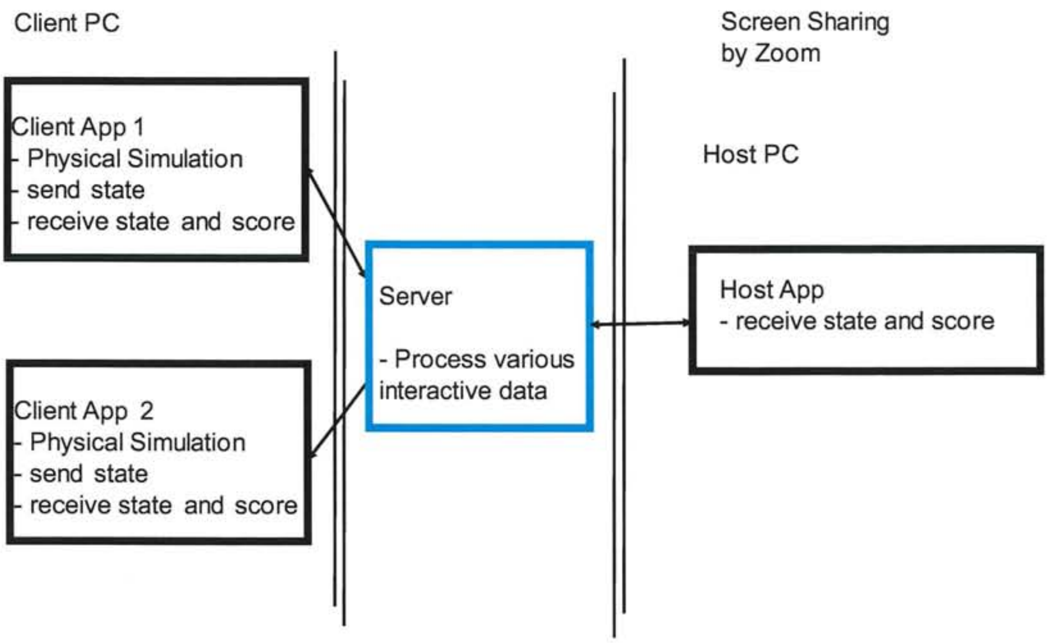


Figure 28. Contest System Architecture

In order to solve the problems encountered in the previous two workshops, the new system updates the network combat system. The new framework is shown in Figure 28. First of all, the server is only responsible for data forwarding between users. After the server is turned on, there is no need for human intervention, which provides convenience for administrators. At the same time, this new E-system provides the possibility for multi-user to use at the same time, and solves the problem of system crash caused by multi-user operation at the same time.

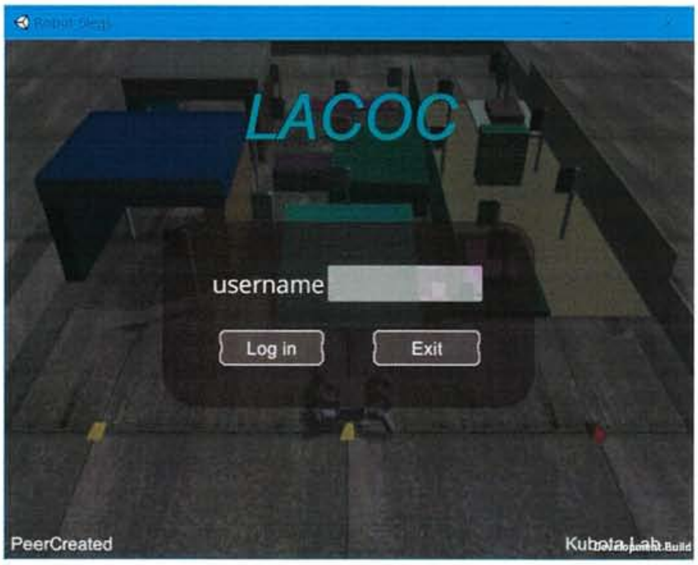


Figure 29. Contest Log in Panel

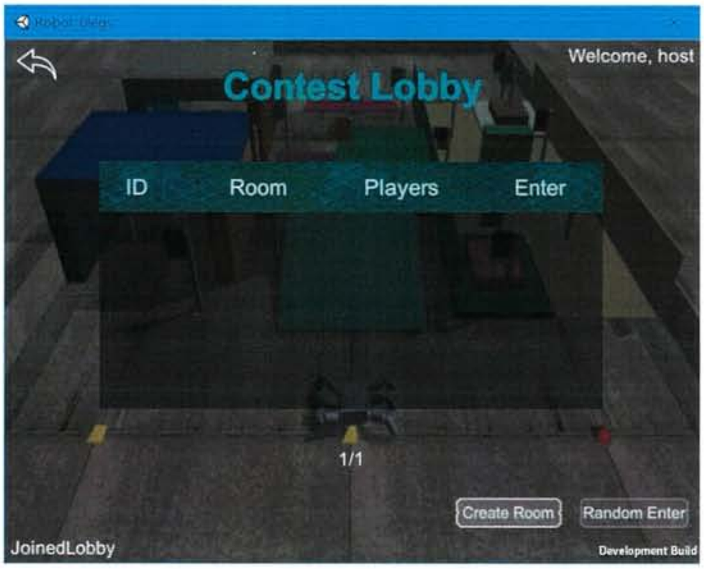


Figure 30. Contest Lobby Panel

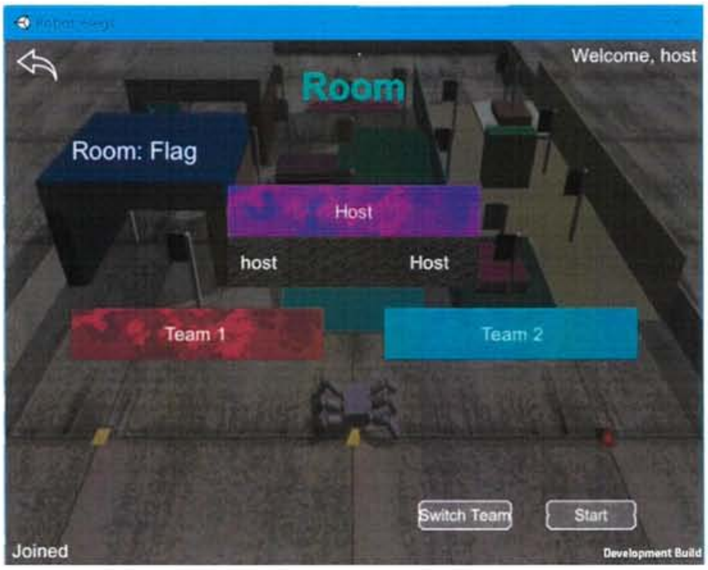


Figure 31. Contest Room Panel

Part of the system interface of the contest system is shown from Figure 29 to Figure 31. At present, users do not need to register. They only need to use any username they want to log in to the system, and then they can use their own robots to participate in the competition.

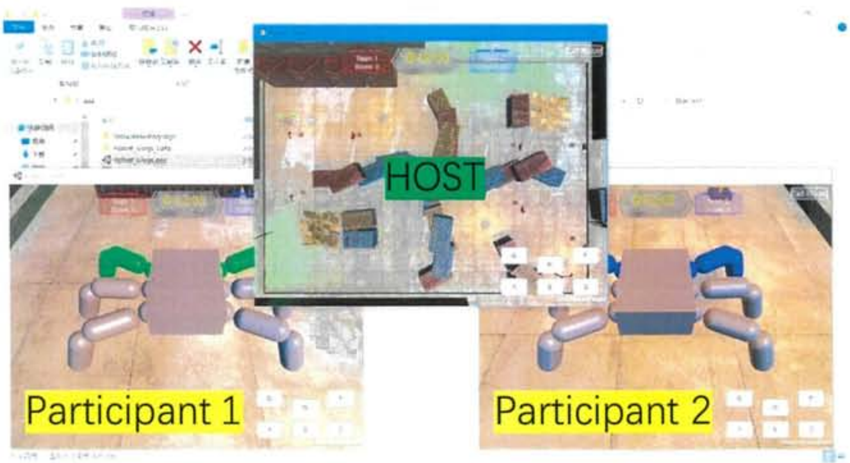


Figure 32. Contest Demo

As shown in Figure 32, this system has developed a spectator mode. The host can observe the operation of the robots of different teams and the score of the game at the same time. The host can simultaneously broadcast the game to other audiences through software such as zoom. The participants only need to use a computer or mobile device. Run the robot simulation program locally and observe the actions of the other party in your own client.

4.3 Learning Support System

4.3.1 Learning support process

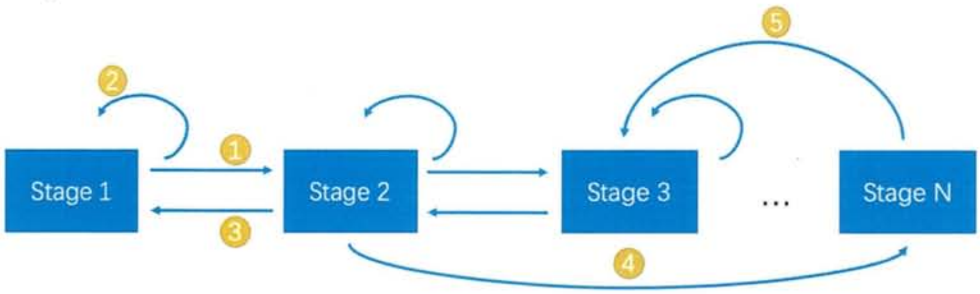


Figure 33. Personalized Leaning Materials Recommendation process

As shown in Figure 33, This E-system will recommend courses to students based on their interests and academic level. According to the description in Chapter 3.3, targeted courses can help students improve their learning motivation. Different stages of learning:

The learning content can be divided into different modules, as shown in the different stages.

For example, the diagram shows 5 different learning processes:

1. Move on to the next chapter

2. Re-study the current chapter

3. Return to the previous chapter

4. Skip some chapters

5. Return to the earlier chapters to learn again

Among them, action 1 and 4 can be classified into one category, and it can be considered that the student's learning process is relatively smooth. Action 2, 3, and 5 are classified into another category, because students may encounter difficulties in the learning process. In this process, it is necessary to help students persist in completing their learning from the perspective of improving students' sense of self-efficiency. So here are 4 Plan, relying on the experiment of the robotics edutainment e-system to demonstrate the effectiveness:

1. Provide choices: Let students have the opportunity to choose the learning process (such as course content, learning methods, learning time, etc.), which may increase students' willingness to invest.

2. Let students lead learning activities: using student-centered teaching methods guide students to find answers on their own.

3. Self-evaluate: If students can reflect on their learning achievements, they will not only have a sense of responsibility for learning, but also continue to care about learning results. Self-assessment allows students to realize that learning outcomes and attitudes are actually in their own hands.

4. Collect and give feedback from students: What do students think about the current teaching resources through the questionnaire? Which topics are of particular interest to them? If the self-study system can collect students' opinions and improve the system according to the students' wishes, students will be more willing to devote their energy to achieve their goals.

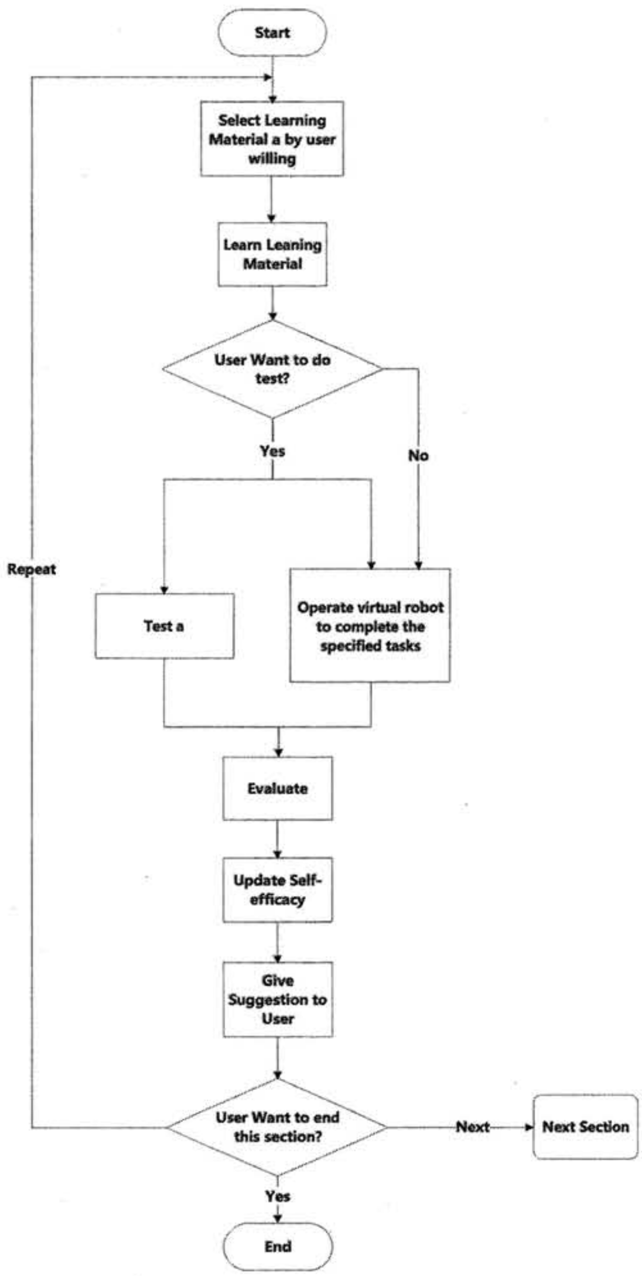


Figure 34. Student Performance Evaluation System

According to the student's learning performance, estimate the student's self-efficacy and learning motivation related to the course, then give suggestions to students for the next course tasks based on it, shown in Figure 34.

4.3.2 Self-efficacy and estimated score calculation method

In order to accurately assess students' self-efficiency, this paper designs the following calculation methods.

General self-efficacy is obtained through questionnaires, and the value is marked as:

$$GS_0 \qquad (10 \sim 40\, points)$$

Every time the user completes a section study, he needs to complete a self-efficacy questionnaire for the current study, and the value is marked as:

$$TS_i \qquad (10 \sim 40\, points)$$

The system records the learning time of the current section, and the value is marked as:

$$T_i \qquad (hours)$$

Number of attempts to answer the question:

$$N_i$$

Actual score:

$$AS_i \qquad (0 \sim 50 points)$$

Estimated score:

$$ES_i \qquad (0 \sim 50 points)$$

The initial ES_1 is estimated based on the user's knowledge background and the degree of interest in robotics courses. Interest in robots(1,2,3 ponits), mechanical knowledge background(1,2,3 ponits), 3D design knowledge background(1,2,3 ponits). Adding the scores of these 3 items will result in a score range of 3-9. Based on this score interval, the first time user score is estimated.

Table 5. Initial assessment form

Estimated initial value	3~4	5	6	7	8~9
ES_1	10	20	30	40	50

The impact factor of learning time is marked as α_i:

$$\alpha_i = \begin{cases} -0.015 & T_i > 2 \\ 0.02 & 0.5 < T_i \le 2 \\ -0.02 & 0 < T_i \le 0.5 \end{cases}$$

The impact factor of the number of responses is marked as β_i:

$$\beta_i = \begin{cases} -0.02 & N_i \ge 4 \\ 0.02 & 1 \le N_i \le 3 \\ -0.03 & N_i = 0 \end{cases}$$

The impact factor of the difference between actual score and estimated score is marked as γ_i:

$$\gamma_i = \begin{cases} 0.03 & \frac{AS_i}{ES_i} \ge 3 \\ 0.01 & 0.95 \le \frac{AS_i}{ES_i} < 3 \\ -0.01 & \frac{AS_i}{ES_i} < 0.95 \end{cases}$$

The system will estimates the self-efficacy value MS_i after each learning task finished based on the TS_i measured this time, the self-efficacy MS_{i-1} estimated by the previous system and the impact factors$(\alpha_i, \beta_i, \gamma_i)$ of each learning:

$$MS_i = \begin{cases} GS_0 & (i = 0) \\ \frac{TS_i + MS_{i-1}}{2} + (\alpha_i + \beta_i + \gamma_i) * MS_{i-1} & (i \ge 1) \end{cases}$$

The calculation formula of ES_i is as follows:

$$ES_i = \frac{AS_{i-1} + ES_{i-1}}{2} + 50 * \frac{MS_{i-1} - MS_{i-2}}{MS_{i-2}} \qquad (i \ge 2)$$

4.3.3 Robotics Course Design

Table 6 provides some examples of the course content that may be taught to students of different levels. These course contents are classified according to the concept of robotics and the students' previous academic level related to robotics.

Table 6. Robotics Course

	Robotics Level		
Robotics Concepts	Novice	Intermediate	Advanced
perception	Direct user observation...	Distance (sonar, infrared) light (encoders, photoresistor) tactile/proximity...	Self-localization and mapping (SLAM), object detection...
Planning/thinking/ control schemes	Teleoperation/remote control...	Obstacle avoidance, potential fields navigation, semiautonomous (via points)...	obstacle avoidance, object tracking, feedback control , behavior-based control...
Acting	Simple touch button remote control...	Forward kinematics, Inverse kinematics, Robot design...	State estimation, state prediction ...

Taking the robot locomotion design for Intermediate students as an example, the daily tasks for holding a 7-days robot workshop are shown in Table 7.

Table 7. 7-day robot contest

	Project
day1	pre-questionnaire
	Overview explanation
	Instructions on how to use
	Exercise
	pre-questionnaire
	Feedback for students
	Estimating self-efficacy
	Selection of next exercise
day2~6	Explanation of the contest outline

	Design guidance for the contest
	Learning robot gait\shape, etc.
	Test run for the contest
	Feedback for students
	Estimating self-efficacy
Day7	Contest
	Post-Questionnaire
	Estimating self-efficacy

Taking this workshop course as an example, the learning Phase of students can be designed into 7 Phase:

1. Basic Knowledge Learning (Preparing Phase):

   Such as rigid bodies, joints, coordinate system, force and reaction force, friction, etc. Students need to learn those knowledge before proceeding with robot design.

2. Posture Design of Leg (Trial Phase):

   Students can change Joint Angle values randomly, then confirm the actual posture of their change. Students can intuitively understand the relationship between joint angles and its corresponding posture by trial and error.

3. Posture Design of Three Legs (Thinking Phase):

   Focus on joints of three legs swing (e.g., left-middle-leg, right-front-leg and right-back-leg). Basically, the robot can stand when three legs contact on the ground.

4. Half cycle of Locomotion Design by two postures (Trial Phase)

   Focus on the design of half cycle of locomotion by two postures. The position of robot should move forward after taking two postures.

5. One cycle of Locomotion Design by four postures (Thinking Phase)

The robot should repeatedly and smoothly change half cycle of locomotion from right side to left side. Furthermore, students need to consider the continuity from the end of one locomotion step to the start of the next.

6. Concept Design of Locomotion (Imagination Phase)

   Natural creatures can take various types of locomotion patterns. This means that it is difficult for you to consider how to design. Therefore, students should consider the concept for the locomotion design, e.g., [pretty], [elegant], [modern], [fearful], [suspicious], [strange], ...

   They may decide the design concept in a group discussion.

7. Creative Design of Locomotion (Creativity Phase)

   Decide the role of locomotion design in a group.

For different Phase, we cloud design some specific tasks for students, and design an evaluation system to let the system automatically grade students.

For example, tests can be used to examine students' mastery of basic knowledge before Phase 1. If students have a good understanding of basic knowledge, when we recommend self-leaning materials, we can suggest that students skip some learning materials.

4.3.3 Evaluation of General Self-efficacy

The General Self-Efficacy Scale is correlated to emotion, optimism, work satisfaction. Negative coefficients were found for depression, stress, health complaints, burnout, and anxiety. The purpose of this study is to improve the students' self-efficacy by using the suggested methods described in section 4.4.1. In order to know whether the self-efficacy of the students has improved, the self-efficacy of the subjects must be accurately measured. Therefore, in this study, we use the "General Self-Efficacy Scale (GSE)"[42].

The questionnaire is shown in Table 8. The total score is calculated by finding the sum of the all items. For the GSE, the total score ranges between 10 and 40, with a higher score indicating more self-efficacy.

Table 8. General Self-Efficacy Scale (GSE)

	Not at all true (1)	Hardly true (2)	Moderately true (3)	Exactly true (4)
1. I can always manage to solve difficult problems if I try hard enough.				
2. If someone opposes me, I can find the means and ways to get what I want.				
3. It is easy for me to stick to my aims and accomplish my goals.				
4. I am confident that I could deal efficiently with unexpected events.				
5. Thanks to my resourcefulness, I know how to handle unforeseen situations.				
6. I can solve most problems if I invest the necessary effort.				
7. I can remain calm when facing difficulties because I can rely on my coping abilities.				
8. When I am confronted with a problem, I can usually find several solutions				
9. If I am in trouble, I can usually think of a solution				
10. I can usually handle whatever comes my way.				

4.3.4 Pre-Questionnaire and Post-Questionnaire

This pre-questionnaire is used for recommending robot learning materials that suitable for students' interests and academic level which is shown in Table 9. Based on the question 1-3, recommend to students what they are interested in. Determine the student's course level based on the question 4-5. Determine how students facing the difficulty of the course task based on the answers 6-9.

Table 9. Pre-Questionnaire

Pre-Questionnaire
1. Are you interested in learning about the various uses of robots?
2. Are you interested in learning about robotics courses?
3. What part of the robot attracts you the most?
4. Are you familiar with programming?
5. Have you understood some basic mechanical design and mechanical principles?
6. Have you used 3D modeling software to design some 3D graphics? For example, CATIA, UG, Solid Works, Blender, 3D Max and other software for model design?
7. What is your practical ability in life (such as repairing alarm clocks, fans, etc.)?
8. How do you generally deal with problems?
9. What is your attitude toward problem solving?

The post-questionnaire is used for investigating weather the virtual robot Edutainment E-system be used as an E-Leaning tool which is shown in Table 10.

Table 10. Post-Questionnaire

Post-Questionnaire
1. Is it difficult to control the virtual robot?
2. Is it difficult to modify the gait of the prefabricated virtual robot?
3. Is it difficult to design your own robot's shape and build your own robot?
4. Is it difficult to design your own robot gait?
5. Are you satisfied that the system recommends learning materials that meet your interests and level?
6. Can learning materials help you learn robot related knowledge?
7. Do you think the whole system is very difficult to use?
8. Will you do more robot learning and research in the future?
9. The knowledge learned in the course may not only be used in robot design. Do you think you may use it in other fields?
10. Are you satisfied with the robot course with this Robotics Edutainment E-system?
11. What do you think are the factors that affect students' learning robot course?
12. What's your comments or suggestions on this Robot Edutainment System?

Chapter V.

Experiments and Results

5.1 Preliminary Experiment

5.1.1 Experiment Outline

We want to test and verify that the system can provide a stable operating environment for students under different platforms, provide a reliable basic platform for the self-learning activities. The experiment content is shown in the table below

Table 11. Content to be evaluated

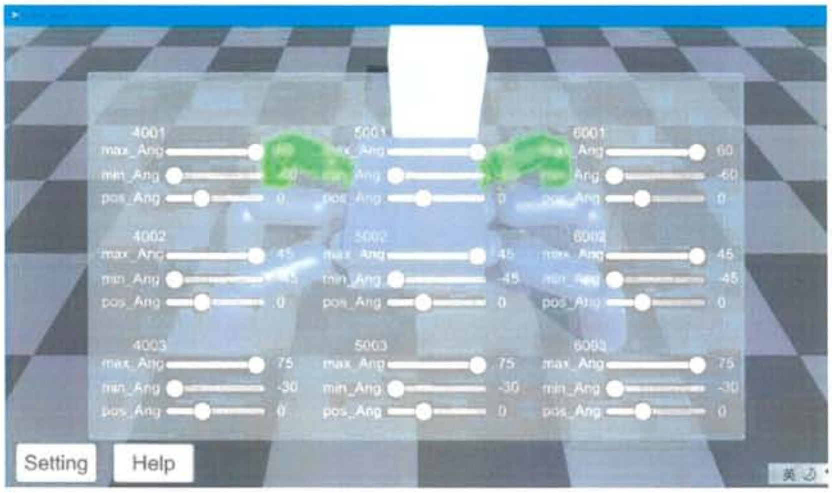
No.	Experiment
1	Cross platform running test of local program
2	Robot gait modification function module test
3	Network battle module test
4	Learning Support System Test

5.1.2 Experiment Result

This E-system has passed the test on Windows, macOS and iOS devices. Under those system, some robot related parameters can be adjusted through the slider bar. Through parameter adjustment, the effect of parameter changes on the robot can be displayed in real time in the interface which is shown in Figure 35.

Figure 35. Local Mode Running on Windows/macOS/iOS

The system allows users to debug various parameters of the robot joints directly on the program interface. After the parameters are adjusted, they can get corresponding feedback on the robot operation interface in real time.



This system also provides users with a more convenient parameter design method, allowing them to modify part of the initialization data more intuitively. The user can save the data that he considers satisfactory after adjustment to the configuration file, and each time it is initialized, the relevant configuration can be directly called.

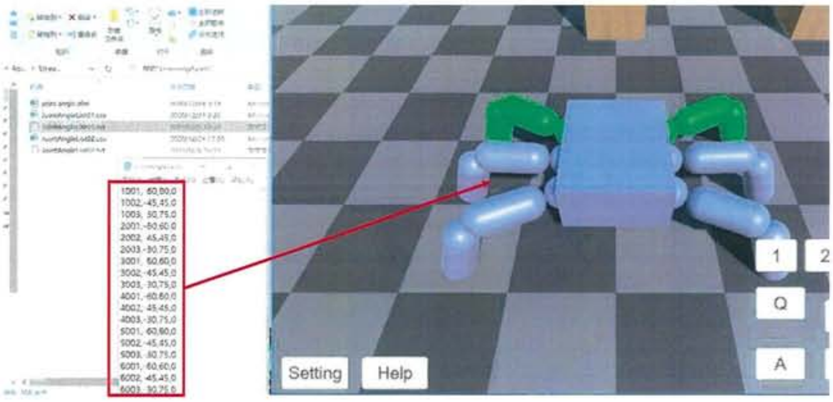


Figure 36. Initialization Data of Joint

By building a server with public IP, students from all over the world can freely access this learning system. As shown in Figure 37, students from different regions can use their familiar operating system to access this learning platform. Host can simultaneously observe the real-time movement and competition status of the robots of the two contestants, and forward the contest status to all contestants through remote conference software such as Zoom/Teams.

Figure 37. Cross-platform Online Contest System Successfully Realized

When users encounter difficulties in actual operation or want to learn related knowledge, they can click the Help button in the interface, and the user will automatically jump to the self-study website we provide. Here you can find the robotics knowledge we provide, covering Part of the basic robotics knowledge, virtual robot design knowledge, and self-study evaluation content.

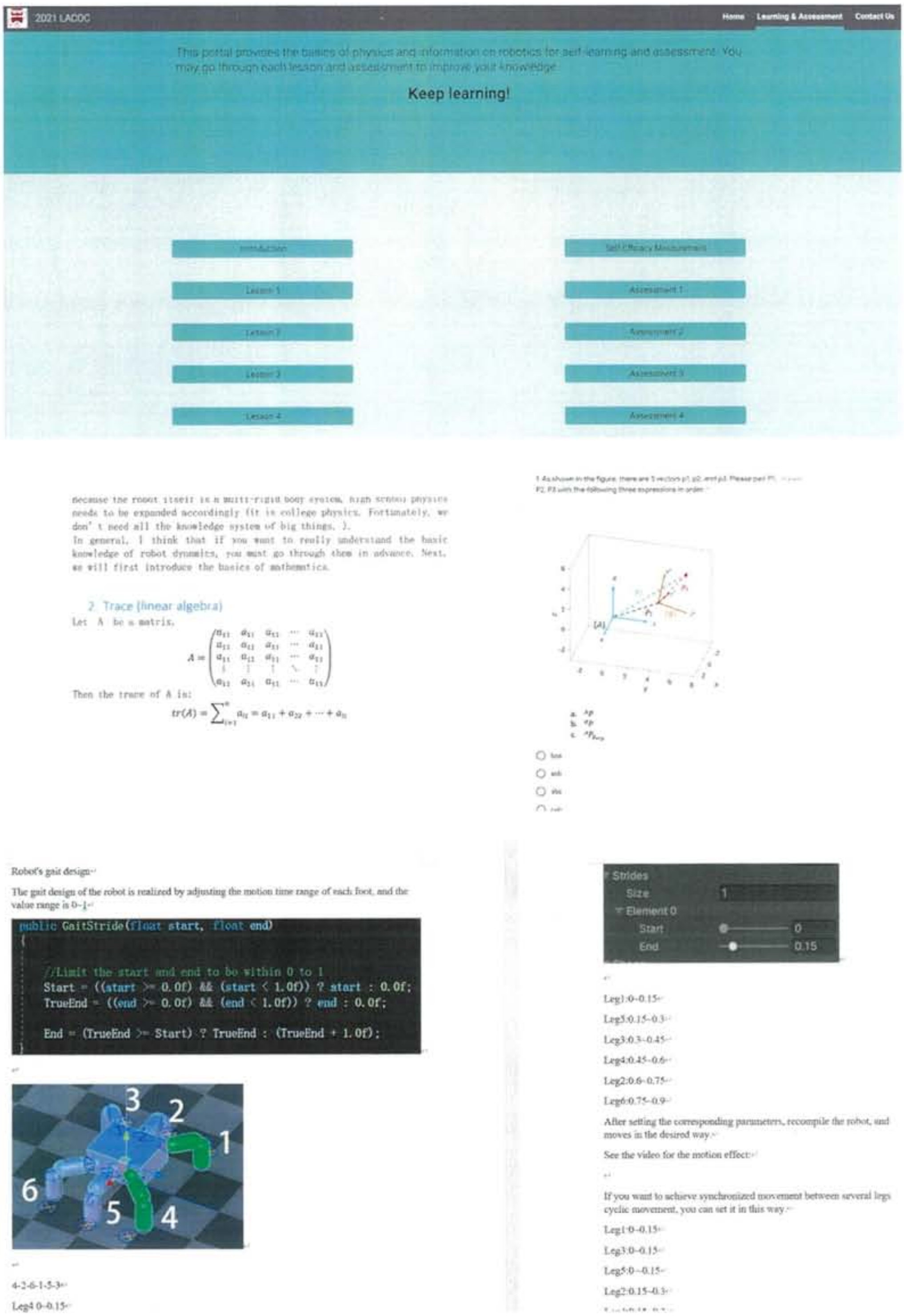


Figure 38. Online self-study support system

In the basic knowledge reserve section, self-study materials, self-study tests and other links are provided. Users can use this robot platform to complete the corresponding learning tasks according to the system recommendation and their own learning willingness. They can also plan their own learning methods.

5.2 Evaluation Experiment

5.2.1 Experiment Outline

During the period from 2021.03.23 to 2021.03.30, a workshop about Learn Robotics & Design of Locomotion Patterns was held. Some students interested in robot design were invited to try out this system. Data related to the learning of students during the trial period of this system was collected. After this workshop, we invite those students continue to use this E-system for one or two weeks. In this process, we collected the data of students' task completion, time spent on self-study, test scores and so on. By analyzing the relevant data of these students, the feasibility of this E-system as an E-Learning Tool was demonstrated.

5.2.2 Experiment Result

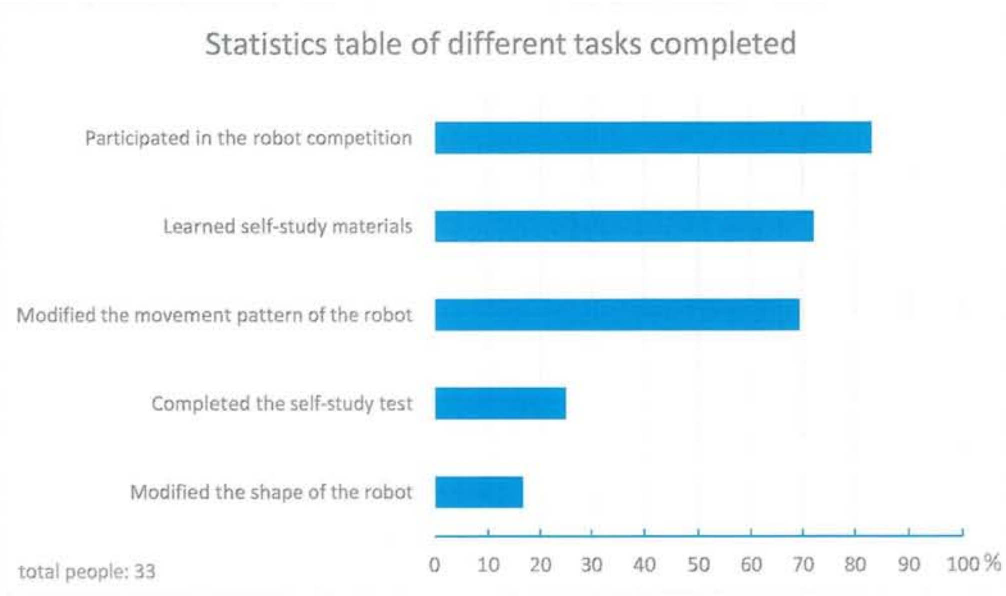


Figure 39. Statistics table of different tasks completed

It can be seen from the completion table of various tasks that more than 80% of the participants in the test are more inclined to participate in the actual operation of robot games. Integrating appropriate game competitive content into self-learning system can help students improve their interest in learning. About 72% of subjects have learnt self-study materials, and most of them can complete relatively easy task, robot movement pattern modification through self-learning. However, there is still room for improvement in the more difficult tasks, such as self-study test and robot shape modification.

Table 12. Background of participants in verification experiment of self-learning promotion support based on self-efficacy

Subject	Preliminary investigation	Detailed information
2	Degree of interest in robots (5 points full marks)	3.5

	Understood some basic mechanical design and mechanical principles or not	Have a certain understanding of mechanical design-related knowledge
	Have used 3D modeling software	Not at all
	GSE score(40 points full marks)	32
	Other	Female, engineering college student She wants to learn robot design and feels that this knowledge is helpful to her
5	Degree of interest in robots (5 points full marks)	3
	Understood some basic mechanical design and mechanical principles or not	Very proficient in knowledge related to mechanical design
	Have used 3D modeling software	Have a certain understanding of 3D modeling software
	GSE score(40 points full marks)	26
	Other	Male, Staff, Engaged in mechanical structure design work Although he is not engaged in robot design, he wants to understand the basics of robot motion
7	Degree of interest in robots (5 points full marks)	4
	Understood some basic mechanical design and mechanical principles or not	Not at all
	Have used 3D modeling software	Have a certain understanding of 3D modeling software
	GSE score(40 points full marks)	24
	Other	Male, Industrial design students Because industrial design is inseparable from basic structural knowledge, he wants to understand the basic structural design principles through this system He is interested in designing the desired multi legged robot without programming
8	Degree of interest in robots (5 points full marks)	2
	Understood some basic mechanical design and mechanical principles or not	Have a certain understanding of mechanical design-related knowledge
	Have used 3D modeling software	Not at all
	GSE score(40 points full marks)	28
	Other	Male, engineering college student

		He wants to learn 3D modeling related knowledge for designing robots
10	Degree of interest in robots (5 points full marks)	2
	Understood some basic mechanical design and mechanical principles or not	Not at all
	Have used 3D modeling software	Not at all
	GSE score(40 points full marks)	17
	Other	Female, liberal arts college student She is not interested in robot shape design and movement principles, but is attracted by online battle games

This table intercepts the data of some representative subjects. In the follow-up results, it analyzes the specific problems encountered by the personnel and the strategies that the system assists them in learning.

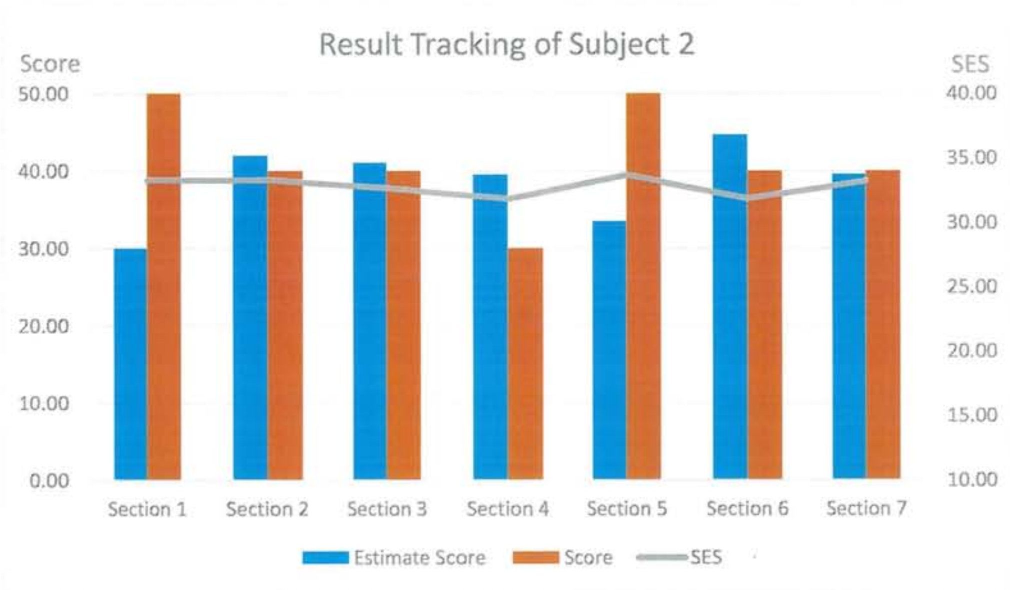


Figure 40. Result Tracking of Subject 2

Subject 2 has a moderate interest in robots, and has a certain understanding of mechanical design-related knowledge, but has a relatively high sense of self-energy efficiency.

Table 13. Personalized learning recommendation

Subject 2	Number of attempts	study-time	reaches the system estimated score	Recommendation
Section1	2	1	Y	Re-study the learning material
Section2	1	1	Y	Go to next Section
Section3	1	2	Y	Go to next Section
Section4	2	3	N	Skip the current test and re-challenge this part after operating the virtual robot
Section5	1	1.5	Y	Go to next Section
Section6	2	2.5	N	Go to next Section
Section7	1	1	Y	Go to next Section

As shown in the above table. After each test, the system will give corresponding learning suggestions based on the scoring results.

For the self-test of section 1, the subject 2 made two attempts. Although the initial results were not satisfactory, after being prompted by the system, she reviewed the given materials for the wrong questions again, and the second test results exceeded the system's predicted scores. For Section 4, there is a requirement for the subject to adjust the robot's movement pattern according to the needs, which involves some basic knowledge for 3D molding. The subject has no relevant knowledge background, so the target score cannot be achieved after repeated attempts. At this time, the system gives a suggestion to skip this part and directly enter the actual operating the virtual robot. After performing some visual practical operations, you can produce a more intuitive impression. Finally, turn back to learn the relevant basic knowledge.

From the perspective of changes in self-efficiency, the learning content and suggestions provided by the system can help the subject maintain a high level. It can be inferred that this subject is likely to adhere to robotics-related learning courses.

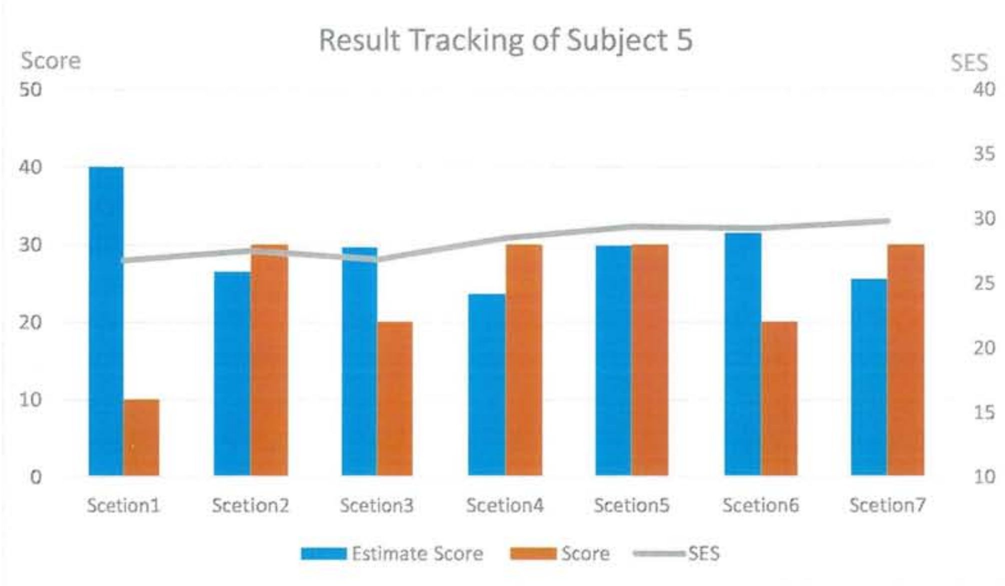


Figure 41. Result Tracking of Subject 5

Subjec5 has a certain knowledge background, because he wants to quickly understand the principles and practical operations of some robot design. Therefore, his expectations of the heart are average, even if his actual score is seriously lower than the system estimated score, it will not cause his self-efficacy reduced. He only want to understand basic using method of this visual robot system throughout the learning process, so we can see that his sense of self-efficacy is slowly rising.

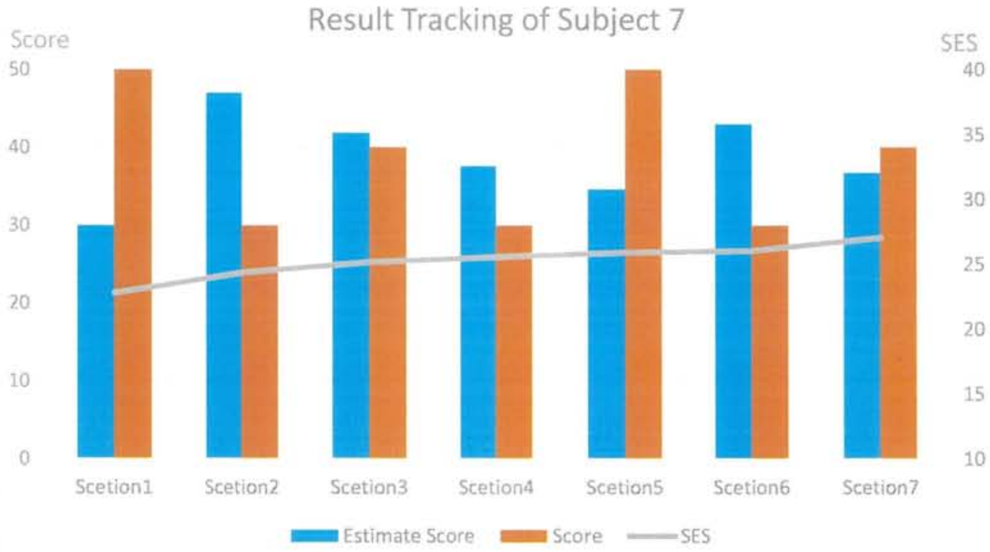


Figure 42. Result Tracking of Subject 7

The situation of Subject 7 is similar to Subject 5. He is very interested in this way of designing his own robot without programming knowledge, so this system can help him continue to obtain the knowledge he wants to learn. In the process of entertainment and learning, his self-efficacy is also showing a state of slowly rising.

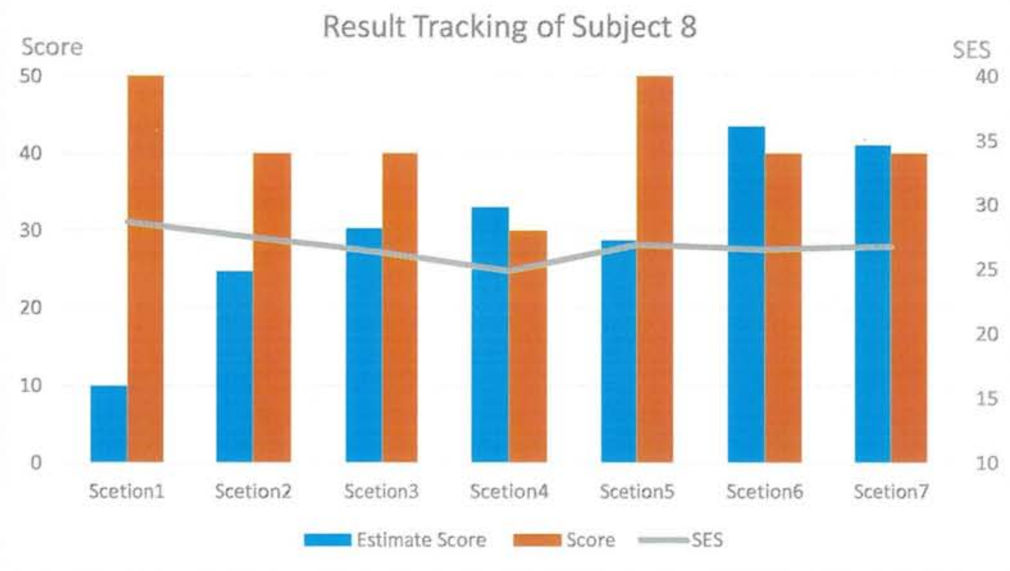


Figure 43. Result Tracking of Subject 8

For Subject 8, his most interesting part is how to design a cool robot. In this experiment, the relevant content provided is relatively small, so although most of the time, he can complete the task very well. The self-efficacy is in a reduced state.

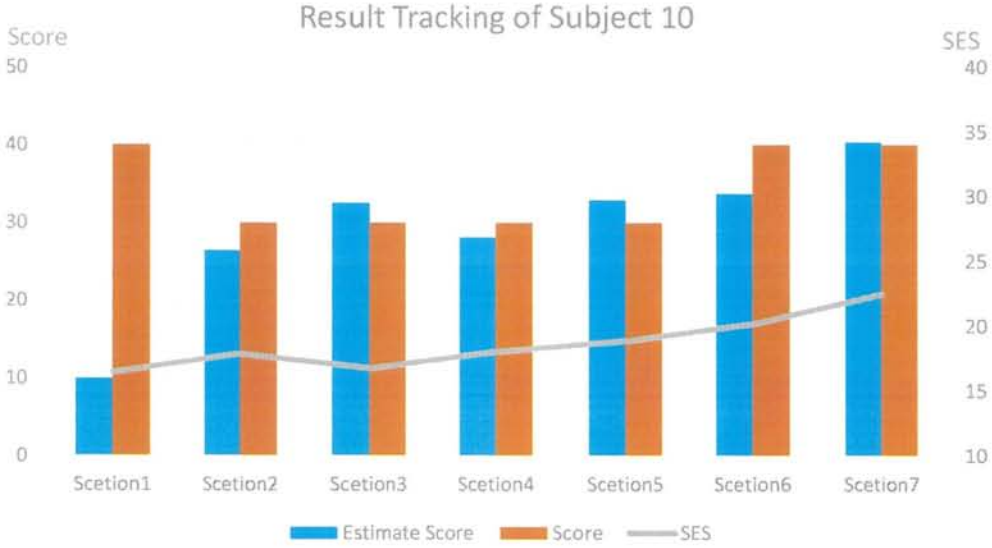


Figure 44. Result Tracking of Subject 10

Subject 10 was attracted by online battle games. She did not have the corresponding knowledge background, but in the process of reasonable course guidance and hands-on operation, she found that the learning of robot-related knowledge is very interesting, and the relevant robot design knowledge meets her own needs. To meet her own needs. So from the final results, her sense of self-efficacy has been greatly improved.

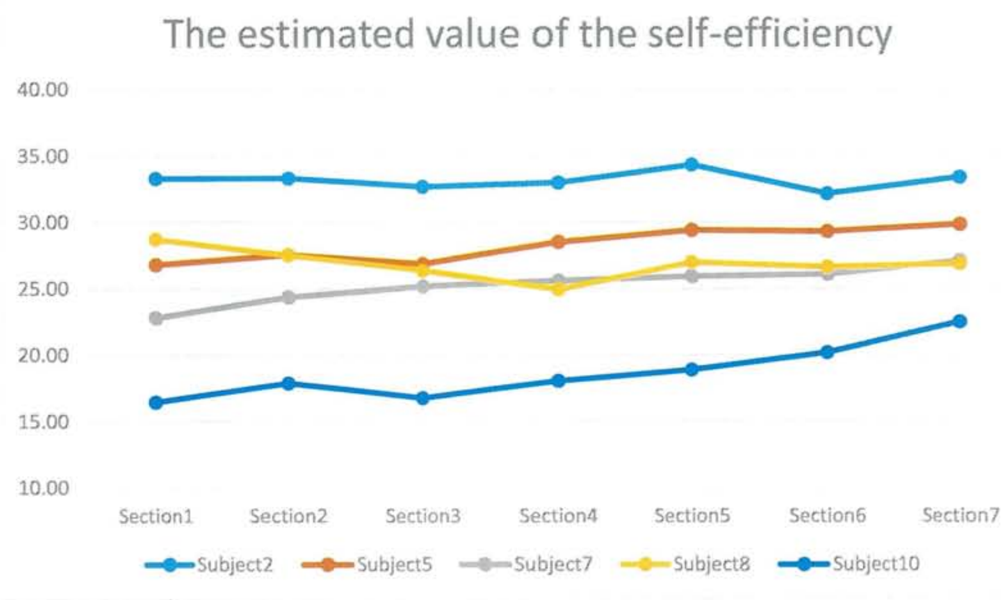


Figure 45. self-efficacy migration map

After Subject 2 completed 7 learning sections, the self-energy effect of the robot's learning can still be maintained at a high level. For subject 5, 7, 10, after completing the 7 learning sections, the sense of self-efficiency has been improved. Subject 8's sense of self-efficacy decreases after all tasks. After investigation, it was found that the reason for the decline in subject 8's self-efficiency is that most of the self-study content currently provided is based on the learning of basic theoretical knowledge of robots, and the self-study content of 3D molding that he is interested in is less than his expectations.

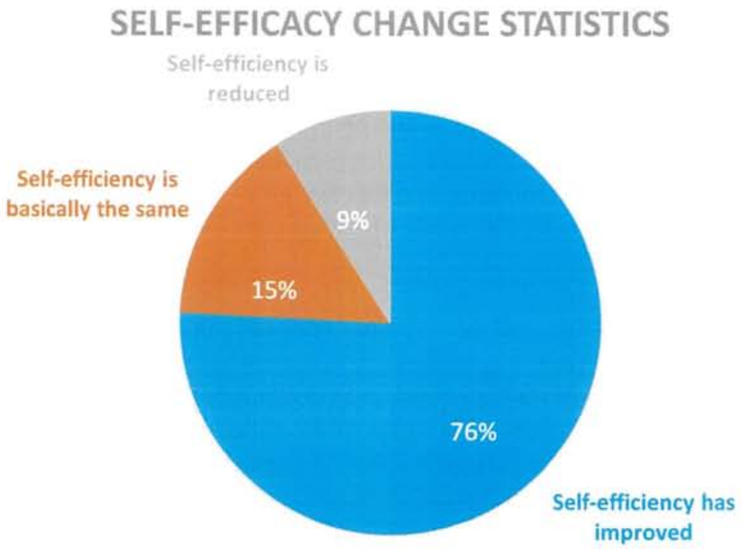


Figure 46. Self-efficacy change statistics

According to statistics, 76% of the participants in the experiment have improved their sense of self-efficacy in robot learning, which shows that the edutainment robotics system based on virtualization technology can help students improve their sense of self-efficacy during the learning process, thereby increasing their willingness to learn. The feasibility of the scheme proposed in this paper is verified.

Table 14 intercepts the overall evaluation of the system by some people. It can be seen that most people like this edutainment robotics system, but the ease of use and course recommendation still need to be improved.

Table 14. Comments and Suggestions

	Comments and Suggestions
Subject 1	I suggest to develop not only six-legged robot, maybe biped, quad robot and other numbers of legs in the future. And also give the student opportunity to design their own mechanical design of the robot, if there is much time for the training.

Subject 2	1.After listening to the author's explanation of robotics edutainment E-system, I found that this is exactly what I need. It really promoted my interest in this system and my vision for the development of this system. 2.The system menu and operation are very friendly for beginners, and the content covers a wide range. In the realization of the basic functions for robot molding and gait design. 3.There is still a lot of things can be improved in the system. For example, adjust the shape of the robot directly in the robot simulation software. If there is an opportunity, I hope I can communicate with the designer face to face and discuss the development method. Look forward to it.
Subject 3	Although I have no experience of designing Robots before, it's interesting to be able to set up robots by myself. It's also good to be able to compete with robots designed by myself, but it's more attractive if there are more different kinds of competitions.
Subject 4	this is interesting, applicable in school, maybe not only for 2 player, the game can use more than 2 player.
Subject 5	It's too difficult to learn about it and I've lost interest in this system.
Subject 6	I hoped that not only the design related to the robot structure can be carried out, but if the design content related to the sensor can be added to this system for analog design. In this way the system will become more interesting.
Subject 7	キーボードまたは画面上ボタンで操作するので、小中学生にも向けた作りになっていると感じます。 高校生や大学生には、ロボットの作成や操作、関節角度の編集も欲しいと思います。 関節角度はアプリ内の他にフォルダ内のテキスト・エクセルファイルから編集できるのでしょうか? 位置や角度設定の初期化もほしいと思いました。
Subject 8	The part I am most interested in is designing cool robot 3D models. This part lacks corresponding learning materials, so it takes more time and energy to research on my own.
Subject 9	I can easily experience the fun of robot design on my mobile phone without purchasing additional equipment, which is very interesting. But the course recommendation part is not perfect.
Subject 10	It is interesting to learn these obscure knowledge through games. The part of the battle game can be a little more, which can stimulate my motivation to design robots.

Chapter VI.

Conclusion

6.1 Summary

In this work, we first proposed the overall system framework of Edutainment System. Based on this system framework, using robotics as the teaching content, subdivided the learning tasks of students at different levels, and then completed the building of Edutainment E-system prototype, and finally collected students' impression on the robot-related leaning materials and the system itself.

In this Robotics Edutainment E-system, we focus on helping students leaning the basic knowledge of robots and the relevant principles and knowledge of robot gait adjustment. We found that the use of virtual robots motivates students' learning motivation and is very willing to explore the knowledge of robots and share their own experience in the learning process. In this E-system, students can observe their modified parameters through experiments. In this way, students are accustomed to problem-solving skills, and are encouraged to discuss and collaborate with other students, improve their ability to communicate with others. Usually, the construction of this knowledge and reflection on the process are essential for maintaining and applying learning in each field. Educational robotics technology establishes a cognitive bridge between educational goals and specific experiences, encouraging students to learn new skills at different levels in an engaging environment.

6.2 Future Work

The robotics education system is not perfect because it is a prototype system. For example, the current system can only use the 6-legged robot to carry out some activities. In the future, we may embed more kinds of teaching resources such as robot design and production cases, using tutorials in this system.

In this study, there are still some problems with this system built with Unity. The first is that the data used to evaluate the user's self-efficacy only has the length of self-study, the actual test and the user's self-efficacy questionnaire after each test. Therefore, it is necessary to add more data to assist in the evaluation of the self-efficacy of the testees, such as adding data such as the length of attention during the self-study process for evaluation. The system used in the second study uses each independent learning chapter for evaluation. Evaluation, there is a certain degree of isolation between tests and operations between each chapter. Therefore, there are problems that the evaluation scores are easy to fluctuate and the evaluation accuracy is difficult to feed back to the participants. Therefore, it is necessary to increase the continuity of the content of each learning chapter, such as adding part of the knowledge in the previous chapter to each test as a scoring standard. In addition, because this research is a short-term experiment with a small number of people, and investigating the self-efficacy of students' learning is a subject that requires long-term large amounts of experimental data. Therefore, it is necessary to increase the number of test subjects and conduct long-term experiments.

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