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Original Article

Development of Technology Design Skills with Mobile Robots for High School Students

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Abstract *- This research focuses on studying environmental problems that affect the learning skills of robotics and automation in technology design. These skills are in high demand in the 21st century. Under the online learning measure, the learners had different knowledge bases and did not know each other. The learners are high school students in Thailand. They are divided into 4 groups. Project-based learning and Problem-based learning are applied to learning management with a case study of mobile robots in different environments. The students are required to design the robots in 3 fields: 1) Movement Mechanism and Structure, 2) Electrical Circuits for Perception and Movement, and 3) Robot Control Programming. In addition, students must design functionalities that serve exploration or industrial purposes, which characterize the designed robots that are practical. The learning system is designed in 9 steps starting from dissolving the learner's behaviors until acquiring the robots that can be used. The results of this study can summarize the environmental factors affecting learning management in 3 aspects, 1) learning equipment, 2) development of the learner's knowledge bases, and 3) methods of learning skills in robotics and automation. The results of this paper can be used as a guideline to enhance skills in robotics and automation that are in high demand today.*

Keywords *- Problem-based learning, Project-based learning, Technology design skill, Mobile robot, High school student.*

1. Introduction

In the current decade, there are a lot of technological opportunities and possibilities resulting in innovations invented and developed. The knowledge of skill development in humans is therefore in high demand. It is undeniable that professions related to the use of design technology and programming skills, as well as systems integrators and robotics are in high demand.[1] This is one of the key opportunities and challenges in human resource preparation. As a result, working people, especially employees, would like to reskill, upskill, and create a new skills. Building human resources capability and capacities for the labour market is one of the most important in Thailand. Robotics engineering is an interesting profession. For further robotics engineering profession, high school students in Thailand are used as the samples. Because the goal for most high school students seeking higher education is to boost their success in the job market, it is very important to prepare these students to cope with changes in technology and knowledge, including advice on educational and career paths for future opportunities. This study, therefore, focuses on developing methods for learning skills for technology design. The format is adjusted to suit high school students. The online learning model is also considered. Currently, the applications of real-world problems in high school education are limited.[2] The learning methods in this paper are therefore designed for solving real-world problems. The designed learning methods are presented in the next sections.

2. Technology Design Skill and Robotics

Technology design is the creation or modification of equipment and technology to meet users' needs. This is very important in enabling innovation to be built in the future. Examples of technology design skills used in a real case are skills required for robotics. The trends shaping the demand for robotics are humanoid, non-humanoid, industrial automation, 3D printing, etc. The industrial robots used for exploration, such as mining, oil, and gas, as well as inspection and maintenance, are also included.

Furthermore, robots are used in the manufacturing process, automotive, and transportation. The adoption of robots has contributed to increasing productivity. Such industries have increased the demand for robots every year.[1,3,4] Robotics is a challenge that requires cooperation between the development of robotics in school-university–industry knowledge transfer because creating innovations that can solve problems is not limited to those who have already graduated.

3. Development of Technology Design Skills

Developing technology design skills through Project-based learning and Problem-based learning is a form of learning that has gained interest in developing students' skills with problem-solving. To develop prototypes and provide expert advice, Project-based learning methods are used. Finding answers to uncomplicated problems can be researched, and come up with short-term solutions. Problem-based learning uses a pedagogy where students gain knowledge about a subject through solving the research component should be supported by the context component and reflected in the contextual information of the problem.[5]

The advantages of problem-based learning are an activity model that encourages the learners to solve problems systematically and rationally. These allow the students to learn and create a problem-solving thinking process that encourages creativity, including critical thinking and analysis.[6,7,8,9]

In addition to acquiring the skills mentioned above, the learners are encouraged to search and collect information systematically. By focusing on the student's work in a team process, the problem is designed with the body of knowledge that the learners have previously studied and can practice from home. Besides enhancing academic knowledge and skills, learning-enhancing activities are also added to the design of technology design skills development methods. The sequence of steps in learning is designed as follows.

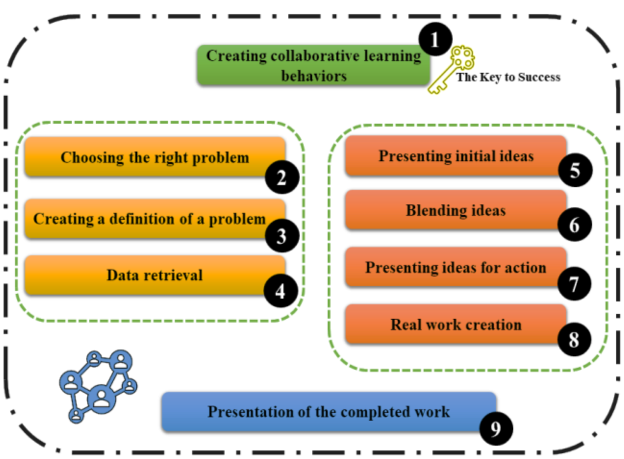

Fig. 1 Activity design diagram

3.1. Step 1 Creating Collaborative Learning Behaviours

Member introduction and dissolution behaviour are investigated. Students who have never met each other before have to do activities together. They familiarize themselves with each other before starting the activity. It will help to relax the learning. A short joint activity to introduce past work and favourite activities related to work are also considered.

3.2. Step 2 Choosing the Right Problem

The problem is chosen at this stage. The teacher will ask the students participating in the project to choose a problem about robots by the voting method. The problems are divided into a mobile robot and fixed robot problems.[10]

3.3. Step 3 Creating the Definition of the Problem

The definition of the problem should be simple and have unlimited ideas. After indicating the definition of the problem, the learner will choose the model of the robot. The teacher is the provided instructor in this step. Additional topic requirements will be provided to allow students to analyse key information points or identify problems, for instance, the size of the working area and working environment.

3.4. Step 4 Data Retrieval

At this stage, the students will have time to search for the information for use in building the robot that can perform tasks and to design a preliminary draft in their way.

3.5. Step 5 Presenting Initial Ideas

This stage is part of the introduction of the presentation of ideas. After the initial design of the robot, the students will be able to present their work to their peers. There will be audience Q&A and expert technical advices.

3.6. Step 6 Blending Ideas

The ideas are combined after the presentation. A brainstorming technique is utilized for the students to gather ideas for solving a given problem by using the idea of the designed robot and using a think pair share teaching technique. This technique is the idea of solving the given problem and sharing or explaining it in class for cases where the robots are very similar, and the learners will choose the models of the robots that will be made.

3.7. Step 7 Presenting Idea for Action

This step is to show ideas for practice. The students design the robots to build in real works. They calculate the structure and feasibility using physics, knowledge of robot technology, mathematics, and engineering fundamentals. This process may repeat several times. After the presentation and assessment by the experts, the students will go to the next step with the final idea.

3.8. Step 8 Real Work Creation

The robot is built so that it works in real environments. In this step, students will be required to create the actual robot as designed and try to use it for real according to the requirements that the problem is given.

3.9. Step 9 Presentation of the Completed Work

The completed work is presented. The students will be required to present the work that their team has designed, including the source and design of the robot. The technical data, the robot's functionality, the security system, real trial and finally, the summarization of the gained knowledge and reflection of learning are presented.

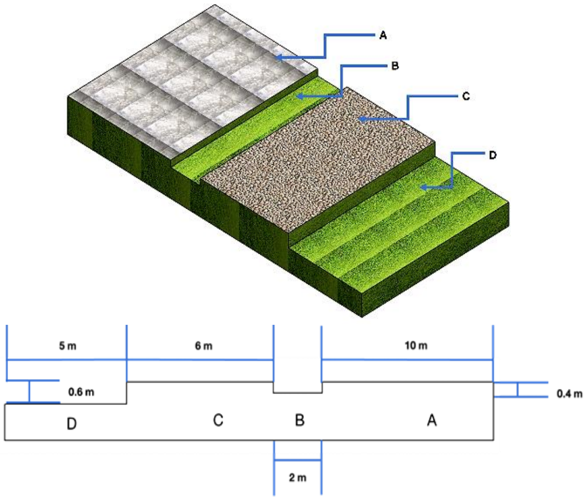

Fig. 2 A problem for the robot that moves on a variety of surfaces. (A) Cement floor. (B) Grass floor. (C) Gravel floor. (D) Grass floor.

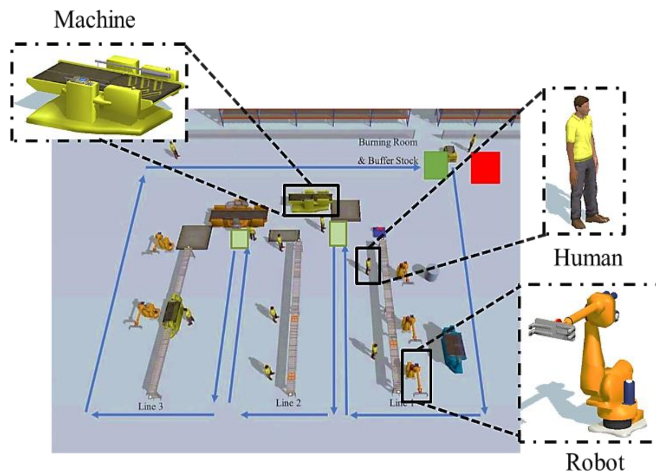

Fig. 3 The mobile robot moves in a variety of environmental conditions, e.g., humans and industrial robots. The blue arrow represents the trajectory of the robot.

4. Case Study

4.1. Designing the Mobile Robots in a Multi-Variety of Terrain Conditions

For the design of the problems of the mobile robots in a variety of terrain conditions, the instructors will require the students to design robots that can move on 3 different surfaces based on surfaces that can be found in school or student homes, such as grass ground, cement ground, and tile ground. In order to make the problem challenging, the area with a different level floor is also used as the condition. This case study is modelled on surface exploration, mining, oil, and gas. The students learn to design robots with motion limitations on various surface conditions and the technology used in exploration.

Examples of requirements given for the students such as

- A multi-surface survey robot must be able to move around a given field. The robot must be able to move from one end to the other and can move back to the starting point automatically.
- The specified surface consists of 3 patterns, starting from the grass floor, the next step is the gravel floor, and the end of the path is the cement floor, as shown in Figure 2.
- The robot must have an anti-collision system in the case of someone walking in front of the robot.
- The robot must have a system that can distinguish the type of surface it moves through.
- The robot must be able to recognize its current position relative to its starting position.
- The robot must be able to display the necessary status for its ease of use, e.g., battery status.

4.2. Design of the Mobile Robots in Industrial Production Lines

For this problem, the instructors must determine the problems using the environment and the actual requirements of the industrial plant.

An example of the problem used in this study is the mobile robot transporting workpieces within the production line of an electronics factory. The students will learn to design the robots under conditions and constraints related to locomotion conditions, including limitations from characteristics that can be encountered in factories, such as dust, heat, and signal noise.

Examples of the requirements given for the students such as

- The robot must be able to move around the designated area automatically.
- The robot must be protected against interference from external environments.
- The robot must have an overload detection system.
- The robot must have an anti-collision system.
- If someone walks in front of the robot, the robot must be able to recharge itself automatically.
- The robot must be able to display the necessary status for its ease of use, e.g., battery status.

5. Learning Activities under the Covid-19 Situation

Participating in activities during the Covid-19 situation is extremely challenging as it transforms the teaching style from a classroom where learners can easily participate and interact in the onsite classroom. It is an online learning format, and it is complicated when students who have never met each other before do the activities together. The activities are thus organized to dissolve the behaviour, and in every discussion, there will be a request for the cooperation of the students to turn on the cameras. Another important thing is to update the work regularly. This prevents mistakes during the robot-building process. For the device problems, it is necessary to use the method of sending the devices to the students' homes by delivering the devices according to the student's responsibility.

For instance, the person in charge of the security system will receive the corresponding sensor. The person in charge of the mechanical work will receive the materials for building the robot. To test the work of the robots that the students must work with together, it is important to have a well-prepared and well-spaced experiment schedule. (During this research time, there was no Antigen Test Kit available to purchase).

6. Real Work

All activities are done using the steps that have been designed. In order to select students for joining this program, the students interested in robotics are recruited from their portfolios. The following is the event information.

6.1. Students Participation in the Program

The students participating in the program are 14 high school students in Thailand from different schools, which are divided into 4 groups.

6.2. Problem Selection

After introducing members and dissolving behavior, the students from each group will choose the model of the robot. It can be noted that students from some groups selected the mobile robot and fixed robot during the comment section. However, during the summary, all 4 groups of students choose the mobile robot problem. Three groups choose the problem of designing mobile robots in various terrains. One group selects the mobile robot's design in an industrial plant's production line.

6.3. Creating the Definition of the Problem

For the group that chooses to design the mobile robots in various terrain conditions, the students must explore the surfaces found on the school grounds or at home to simplify the experiment. Team B chose to design the mobile robot for the industrial production line; the surface condition chosen is the large tile floor. The surface conclusions are as in Table 2. The level of complexity of the two selected topics is maintained to be similar.

Table 1. Information on the student problem selection

Team	**Team Information**	
	Selected topic	***Members***
A	Design of the mobile robot in a variety of terrain conditions (Type A)	4
B	Design of the mobile robot in the industrial production line (Type B)	4
C	Design of the mobile robot in a variety of terrain conditions (Type A)	3
D	Design of the mobile robot in a variety of terrain conditions (Type A)	3

Table 2. The texture of surface selection

Team	**Team Information**	
	Selected texture	***topic***
A	The grass floor, sand floor, cement floor, and different surface levels.	Type A
B	The tiled floor includes humans and industrial robots in the environment.	Type B
C	The grass floor, gravel floor, cement floor, and different surface levels.	Type A
D	The grass floor, gravel floor, cement floor, and different surface levels.	Type A

6.4. Data Retrieval

The students are required to identify the features and limitations that can cause problems with the robot's movement. The concrete floors are slippery and can cause the robot to slip. The grass areas after the rain often have puddles, making it an obstacle to the robot's movement.

6.5. Presentation of Initial Ideas

Each student has a presentation that expresses their creativity. Different robot models are presented. The robots that use wheels to move, the crawler-based robots or the robots that use their legs to move, bio-inspired robots and robots with integrated movements, such as crawlers and legs. It can be noticed that some students can draw beautiful and easy-to-understand sketches of the robot. Whereas some students can design a workpiece with the 3D design program for the presentation. For some students, however, the draft of the robot cannot be displayed.

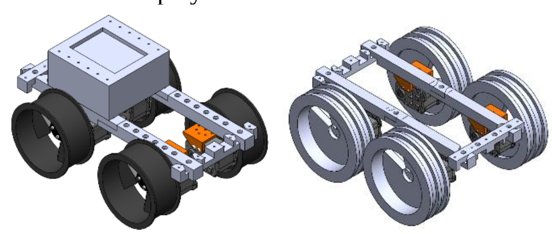

Fig. 4 An example of robot initial ideas.

6.6. Blending Ideas

For groups A, C, and D, the mobile robots are designed in various terrain conditions. The selection of the robot design is shown in Figure 5.

- For group A, the students choose to design two robots that use crawler tracks, one for movement and the other one that looks like legs for crossing obstacles on a different level.
- For group C, the students chose to develop a 4-wheel drive robot, which has 2 adjustable propellers mounted on the robot to help for creating the suction for the robot to adhere to the leveled ground with steep slopes to allow crossing.
- The students in Group D design a puppet that moves like a snake and can glide through various surfaces.
- Designing the mobile robot for the industrial production line, Group B chose to design an AGV-like robot used in the industrial plant.

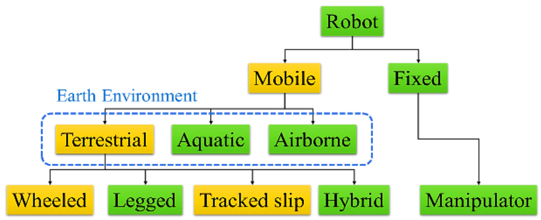

Fig. 5 Selection of the robot design for solving the problems. The orange blocks represent the selected robot type

6.7. Idea Presentation for Action

This section is a significant part. The students design the workpiece that illustrates the robot's concept and detailed shape. This includes the sequence of the steps and functions. There are calculations and reasons for choosing to use various devices.

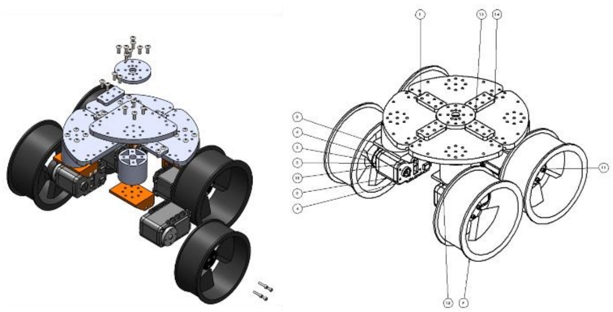

Fig. 6 An example of the final robot design for solving the problems

6.8. Real Work Creation

In this section, the students create a piece of work as they have been designed. They may face problems and obstacles in a variety of ways. The problems can be categorized as follows.

- For the problems in forming workpieces, due to the diverse nature of the robot, the students must use a variety of forming patterns, i.e., the lasers cut, 3D printing of plastic parts, formation, and decoration of the workpiece. This can lead to making mistakes and is potentially dangerous for the students. This problem can be solved by taking care of and advising with short-term training by the experts.
- For the problems encountered during the robot trial in the actual location these events can occur for many reasons, both from external factors (environment) and internal factors (the dislocation of the robot). This includes the problem that will occur if it affects the safety of the students. The students are allowed to design their own solutions to solve the problems and search for information.

6.9. Presentation of the Completed Work

The final step of the activity is where the learners must show all the results they have learned since the start of the activity by pointing out the importance or benefits of the chosen problems by their group. The process of creating a piece of technical information that supports design thinking. This includes the work that the robots can be applied in the future and the robot's functionality, which allows the robot to work more perfectly.

Fig. 7 An example of the robot designed by the students participating in the project

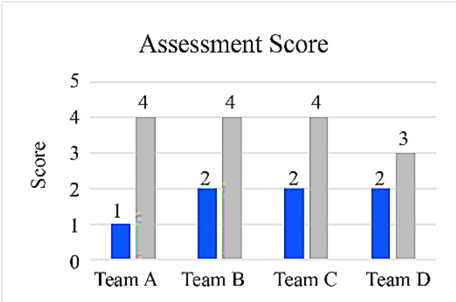

Fig. 8 Average score of assessment of technical design skills. Blue color represents design skills in robotics before the project. Gray color represents design skills in robotics before the project.

After the end of all activities, students' learning outcomes in the 4 team projects on 3 topics are measured, consisting of the understanding of the work, development of 3D part design, and robot programming skills. By asking and evaluating the work that students can do, it can be found from the assessment shown in Figure 8 that the average score of all teams is increased. There was no significant difference in skill development in Type A and Type B case studies.

With the case studies presented in this paper, both designing the mobile robots in a multi-variety of terrain conditions and design of the mobile robots in industrial production lines, students were able to demonstrate an increase in skills in the understanding of the work, development of 3D part design, and robot programming skills, from 20% - 60% increase in evaluation.

7. Conclusion

This paper investigates the development of technical design skills based on project-based learning and problem-based learning among high school students. The problem design aspect should be at the level of knowledge that the students can explain from the base knowledge they have studied or are studying at the high school level. It is necessary to define the scope of work and activities for them to prevent possible confusion. This is the model that encourages students to learn all around, but at the same time, the requirements should not be overly restricted unless it is beneficial for the safety of the students in the design of the learning process.

In the design of the learning process, the key to making all activities possible is creating collaborative learning behaviors so that the students can create effective solutions for the time and nature of the problem.

Table 3. Steps, activities, and indicative teaching strategies for the implementation

Step	Activities	Teaching Strategies
1. Creating collaborative learning behaviors	Breaking the ice with your introduction, past activities in robotics and questions to know each other more.	- Brainstorming - Discussion - Formulating questions
2. Choosing the right problem	Choosing the problem with robots is classified into 2 categories, mobile robot and fixed robot problems.	- Brainstorming - Discussion
3. Creating the definition of the problem	Topic requirements to allow students to analyse key information points or identify problems.	- Brainstorming - Discussion - Guided exploration - Question and answer
4. Data retrieval	Search for information to use in building the robot.	- Discussion - Think pair share
5. Presenting the initial ideas	Expert technical advice.	- Guided exploration - Presentation - Question and answer
6. Blending ideas	The idea of solving a given problem and sharing or explaining	- Brainstorming - Think pair share
7. Presenting ideas for action	Possibility checks such as the calculation of structure and feasibility using physics, knowledge of robot technology, mathematics, and engineering fundamentals.	- Presentation - Question and answer
8. Real work creation	Real work according to the requirements of the problem.	- Experimentation - Practicing
9. Presentation of the completed work	Summarizing the knowledge gained and reflecting on the learning.	- Assessment - Presentation - Question and answer

It can be concluded that the steps and processes, including the observations and problems presented in this research, will be useful for the development of technical design skills by using problem-based learning among high school students.

8. Future Work

Due to all the self-made equipment by students, it takes a lot of time and wastes students' opportunities to learn additional skills, such as programming skills. A robot kit will be developed in the near future to promote students' learning. Moreover, to develop the basis for domestic students in robotics and automation, a course on robotics that integrates physics knowledge, robot technology, mathematics and engineering fundamentals will be created for high school students in Thailand.

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