Implementation of Educational Robotic into Teaching-Learning Process to Enhance Students Skills in the Science and Technology

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Implementation of Educational Robotic into Teaching-Learning Process to Enhance Students Skills in the Science and Technology

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Abstract. The educational development in the sector of science and technology is needed to anticipate technological advances in the challenges and changes of the Industrial Revolution 4.0. The society of education must prepare its students to be able to follow these challenges and changes by using a learning process that uses robots or what is known as Educational Robotics (ER). The objectives of this study are to identify what kinds of skills can be trained in the learning process using ER and to evaluate what types of robots can be applied to the learning process in the sector of science and technology. The research to be carried out is a literature review research. The research method is the Comprehensive Literature Review that has three phases that are 1) exploring phase, 2) interpretation phase, 3) communication phase. The research results showed that ER can be used for the learning process in developing the skills needed by science and technology education. These skills include programming skills and computational skills, communication, and collaboration skills, problem-solving, and creative thinking. The type of robot that can support the ability of students' skills is an assembled robot type that must be composed at the beginning to learn a robot by the students. Meanwhile, the built-in robot type is more limited in its usefulness for the teaching-learning process because it is more specific. The implication of this research is to provide information on the selection and utilization of appropriate ER in science and technology.

Keywords: Educational robotic, Programming skill, Teaching-learning process, Computational Skill, Comprehensive Literature Review

1. Introduction

The development of the digital era is in line with the objectives of implementing the Industrial Revolution 4.0 era, today. The Industrial Revolution 4.0 was raised by the German government in 2011 to be brought into the world a new heading as the fourth industrial revolution (Wagner, Herrmann, Thiede, 2017) (Carvalho & Cazarini, 2020). Meanwhile, the objectives of the Industrial Revolution 4.0 are to work with a higher level of automation achieving in order to reach a higher level

of operational productivity and efficiency and to digitize the information (Peruzzini, Grandi, & Pellicciari, 2017).

Based on the objectives of the Industrial Revolution 4.0, the main challenges that arise are automation and digitization. Therefore, the readiness of human resources is needed in facing these challenges. In the meantime, the human resources skills are most required by Industrial Revolution 4.0 to be mastered such as Complex Problem Solving, Critical Thinking, Creativity, People Management, Coordinating with Others, Emotional Intelligence, Judgment, and Decision Making, Service Orientation, Negotiation, and Cognitive Flexibility (Forum, 2018). In the field of education, four basic competencies are needed, such as competence of professional, competence of methodological, competence of social, and Personal and Self-competence (Eberhard, et al., 2017). Figure 1 shows the 21st Century Skills needed by human resources to achieve a job (koolkatscience, 2019). The skills stated by (Eberhard, et al., 2017) and (koolkatscience, 2019) are part of the required skills in Industrial Revolution 4.0.

Figure 1 The 21st Century Skills

In the automation process, robots play an important role because of their ability to work according to the given computer program to complete their tasks. Robots have been widely used to make various industrial products. This is because robots can increase efficiency and effectiveness in producing a product. The manufacturing paradigm is shifting production rapidly from mass towards customized production. Robots are required for as reconfigurable automation technology. Processes such as product development, manufacturing, and assembling phases, are more efficient and effective in case robots are used to handle these manufacturing systems (Alcácerac & Cruz-Machado, 2019).

The education sector especially the field of science and technology must also prepare students to be able to follow the changes and challenges of the Industrial Revolution 4.0. One of the changes and challenges of the Industrial Revolution 4.0 is automation technology. Thus students must be familiar with and be able to use this automation technology. One of the technologies is a robot. Robots can be used in helping to study material in science and technology. The use of robots in the learning process is often referred to as educational robotics. The purposes of this study are to identify what skills can be taught in Educational Robotics and to identify what types of robots in education can be applied to learning science and technology. The originality of this study is to conduct literature reviews of several studies related to the use of educational robotics in the fields of science and technology and to identify these literature reviews in four aspects, namely learning materials, development skills, types of robots, and study levels which are also related to the field of science and technology.

2. The Development of Educational Robotics

In general, robots are defined as "a system to sense external environments and execute appropriate physical motions or functions based on achieved information" (Misaki & Arai, 2011). Based on this definition, the robot can work according to the input given by the user or system. The input can be in the form of sensors or computer programs that have been implanted in the robot microprocessor. Along with the concept of how robots work, robots can be used for science and technology learning. Learning that can be done is related to the robot itself, for example, to learn how the supporting components work, to learn how to program so that the robot can move or act following the program programmed on the robot. Some researches indicate that robotics have an effect on many educational aspects and have a large effect on students' abilities and skills (Kawazoe, Mitsuoka, & Masada, 2011).

Educational Robotics has been widely applied in the world of education, from early childhood education to university level (Maximova & Kim, 2016) and even to train teachers before implementing their knowledge in the classroom (Kim, et al., 2019). This study shows the important role of robots in helping the teaching and learning process. Most of the learning materials that can use robots are related to the scientific field, for example, to understand Engine Principles and Practice (Liao, Liao, Shih, & Lin, 2016), STEM concept (Bacca-Cortés, Florián-Gaviria, García, & Rueda, 2017), control systems (Elamvazuthi, et al., 2015), electrical engineering and computer programming (Chou, 2018), electromechanical (Buditjahjanto, Ardi, Munoto, & Samani, 2020).

2.1. The type robot for Educational Robotic

There are many types of robots used for education. In general, the type of robot for education is divided into two, namely the built-in robot and the assembled robot. The built-in robot type can be directly used by the user for learning but has drawbacks because of its limited use. Meanwhile, the use of assembled robots must be assembled with robot components first. When assembling the components of this robot, students can study each performance of the parts that make up the robot until finally the robot is completely reconstructed and can work according to its function. Each of these types of robots has its respective advantages in their use in the learning process. The build-in type robot is suitable for the learning process that is used to observe a robot's performance. Meanwhile, the build-in type robot weakness is its limited use in learning science and technology material (González & Muñoz-Repiso, 2018). Whereas robots with the assembled robot type have a wider and more flexible designation because they are adjusted to the material being studied (Sullivan & Heffernan, 2016).

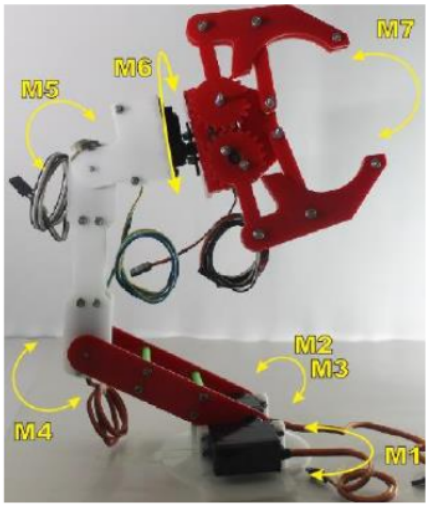

Figure 2 Assembled robotic arm

Figure 2 is an example of an assembled robot type in the form of a robotic arm. The robot components consist of manipulators, gripers, arms, joints, links, and servo motors which are assembled to form a robotic arm. Furthermore, the robotic arm is used to study its movements. The servo motor on the robotic arm consists of 7 motors, each of servo motor which has the task of moving according to the program entered. This robotic arm can be used to teach students to observe robot movements and create programs to pick up and move items according to orders on student worksheets that use the concept of problem-solving learning (Buditjahjanto, Ardi, Munoto, & Samani, 2020).

2.2. Skills in Educational Robotic

The use of Educational Robotics in learning can help students to understand learning material, especially in the science and technology field. Science and technology is a field that is quite difficult for students to become experts because it requires certain skills. According to (Maat, 2017) the main skills that can be developed are 4C (Creativity, Critical Thinking, Communication, and Collaboration) in the STEM field as part of the science and technology knowledge. Educational Robotics used in learning can be used to teach skills, including programming skills (Bacca-Cortés, Florián-Gaviria, García, & Rueda, 2017) (González & Muñoz-Repiso, 2018), psychomotor skills (Buditjahjanto, Ardi, Munoto, & Samani, 2020) (Chang & Chen, 2020), problem-solving (Kim, Kim, Yuan, Hill, Doshi, & Thai, 2015) (Elamvazuthi, et al., 2015), and Computational Thinking (Chookaew, Howimanporn, Pratumsuwan, Hutamarn, Sootkaneung, & Wongwatkit, 2018) (Sullivan & Heffernan, 2016).

3. Method

This study used the Comprehensive Literature Review (CLR) method (Onwuegbuzie & Frels, 2016). The CLR method has seven steps, such as 1) Exploring Beliefs and Topics, 2) Initiating the Search, 3) Storing and Organizing Information, 4) Selecting / Deselecting Information, 5) Expanding the Search to Include One or More MODES (Media, Observation (s), Documents, Expert (s), Secondary Data), 6) Analyzing and Synthesizing Information, and 7) Presenting the CLR Report. This CLR method has 3 phases consisting of the seven steps, namely Exploration Phase (Exploring Beliefs and Topics, Initiating the Search, Storing and Organizing Information, Selecting / Deselecting Information, Expanding the Search to Include One or More MODES (Media, Observation (s)), Documents, Expert (s), Secondary Data)), Interpretation Phase (Analyzing and Synthesizing Information) and Communication Phase (Presenting the CLR Report). Figure 3 shows the phases and steps of the CLR method.

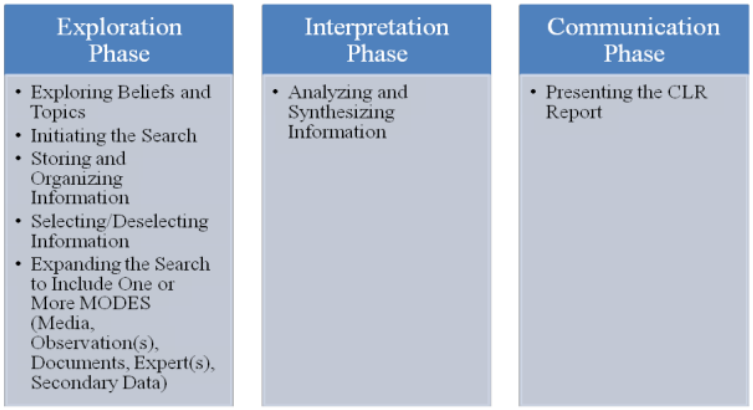

Figure 3. Comprehensive Literature Review (CLR) method

4. Result

Phase 1 of the CLR method is the Exploration Phase. At this stage, the results of the literature review searches obtained several articles related to the use of Educational Robotics for learning. The learning topics collected is those related to science and technology materials and skills that can be developed during the learning process using Educational Robotics. Table 1 shows the results of the literature review in phase 1. In Phase 2, namely, the Interpretation Phase, an analysis is carried out by categorizing the use of robots based on learning materials, skills developed, types of robots, and applied strata. Learning materials are related to science and technology that can use Educational Robotics as a learning medium. The learning materials are programming, engine principles and practice, STEM concepts, control system electrical engineering and computer programming, and electro-mechanical. Learning using Educational Robotics can also develop skills such as programming skills, learning motivation and learning attitudes, problem-solving skills, computational thinking, and psychomotor skills.

Table 1. The literature review based on educational robotics

Reference	Learning material	Development Skill	Type of Robot	Study level
(González & Muñoz-Repiso, 2018)	Programming challenges, called Solve-Its.	programming skills and computational thinking	Bee-Bot floor robot (Build-in robot)	Early childhood education
(Keren & Fridin, 2014)	Geometric	Metacognitive	Kindergarten Social Assistive Robot (KindSAR) (Build-in robot)	Kindergarten
(Fridin, 2014)	Storytelling	constructive learning	Kindergarten Social Assistive Robot (KindSAR) (Build-in robot)	Preschool education
(Misaki & Arai, 2011)	Actuator and sensor	Problem-solving	Micro-robots (assembled robot)	Elementary and middle school pupils
(Liao, Liao, Shih, & Lin, 2016)	Engine Principles and Practice	Learning motivation and learning attitude	LEGO Robots (assembled robot)	Vocational Schools
(Bacca-Cortés, Florián-Gaviria, García, & Rueda, 2017)	STEM concepts	Programming skills	UVBots2 Mobile robotics (assembled robot)	Undergraduate students
(Elamvazuthi, et al., 2015)	Control system	Solve problems and complete projects	LEGO Mindstorm (assembled robot)	Undergraduate students

(Sullivan & Heffernan, 2016)	STEM	Computational thinking and problem-solving abilities	robotics construction kits (RCKs) (assembled robot)	Junior high school
(Chou, 2018)	Electrical engineering and computer programming	Problem-solving skills	Robot MakerSpace assembled Arduino-based robots from scratch (assembled robot)	Elementary school
(Chookaew, et al., 2018)	STEM programming, electronics, and robotics	Computational Thinking	mBot (assembled robot)	Senior high school
(Kim, et al., 2019)	STEM	Basic cognitive skills and problem-solving	RoboSTEM (assembled robot)	pre- and in-service teachers
(Chang & Chen, 2020)	STEM	Psychomotor performance	Sailboat robotics (assembled robot)	Senior high school
(Buditjahjanto, Ardi, Munoto, & Samani, 2020)	Electromechanical	Psychomotor skills	The robotic arm (assembled robot)	Undergraduate student
(Ohnishi, Honda, Nishioka, Mori, & Kawada, 2017)	Programming	Programming skills	Autonomous robot (assembled robot)	Elementary and Junior High School Students

The use of Educational Robotics concerning with science and technology learning can be used from early education until undergraduate programs. The most type of robot used in the learning process is the assembled robot than the build-in robot type. The types of assembled robots are used in the learning process such as Micro-robots, LEGO Robots, UVBots2 Mobile robotics, LEGO Mindstorm, robotics construction kits (RCKs), Robot MakerSpace, mBot, RoboSTEM, sailboat robotics, Robotic a, Autonomous robots. Furthermore, in the 3rd phase, namely the Communication Phase, it is shown in the discussion section, where the research results are linked to relevant research.

5. Discussion

The results of the literature review search show at the skills can be used in educational robotics are in line with the skill requirements needed in the Industrial Revolution 4.0 era. It is supported with the research of (Carvalho & Cazarini, 2020) which states that Industrial Revolution 4.0 emphasizes automation which is often found in the field of robotics. Moreover, Industrial Revolution 4.0 is as part of the 21st-century, where the 21st-century skills are social and cross-cultural skills, students' creativity, communication skills, self-direction, collaboration and team-working and social responsibilities. These skills can be implemented in educational robotics are also following the skills needed in the 21st-century era as mentioned in (Forum, 2018). Khanlari, 2013) stated that robotics is an effective tool to fulfill the need for 21st-century skills. Therefore, robotics can be used as an effective media learning to prepare students for the 21st century.

The usage robot in education can train skills such as programming skills (Ohnishi, Honda, Nishioka, Mori, & Kawada, 2017), learning motivation, and learning attitude (Liao, Liao, Shih, & Lin, 2016), problem-solving skills (Misaki & Arai, 2011), computational thinking (Chookaew, et al., 2018), and psychomotor skills (Buditjahjanto, Ardi, Munoto, & Samani, 2020). Similar thing, (Kim & Jang, 2019) stated that problem-solving skills and computational thinking are needed for today's work abilities in the face of competition. The educational robotics also can help students to understand and enhance their knowledge and cognition in the field such as Electrical engineering and computer programming (Chou, 2018), STEM (Bacca-Cortés, Florián-Gaviria, García, & Rueda, 2017), (Kim, et al., 2019), (Sullivan & Heffernan, 2016), control system (Elamvazuthi, et al., 2015), electromechanical (Buditjahjanto, Ardi, Munoto, & Samani, 2020).

The assembled robots are the most used in the Educational Robotics. This is because the assembled robot is designed according to the needs of the learning material and the skills that are trained in the learning process. The teachers who used education robotics have proved that robot usage in the class is very useful. The education robotics meets with the needs of media learning in the field of education (Misaki & Arai, 2011). Assembled robots have the advantage of helping students to learn a learning material gradually until all the components that make up the robot are arranged. It is supported by (Sullivan & Heffernan, 2016) stated that robots with reconstructed models are easier to be rebuilt and easier to adjust the learning material and skills that are trained to students. The implication of this research is to provide information on the selection and utilization of appropriate ER in science and technology and also to inform that the skills trained in the use of Educational Robotics are in line with the needs of Industrial Revolution 4.0.

6. Conclusion

The changes and the challenges facing education today are in the era of automation and digitization. The use of Educational Robotics is expected to overcome these changes and challenges. For automation problems, robots as learning media can help students to understand the automation process such as robot movement and work functions of robot efficiently. Meanwhile, for digitization problems, students can learn robots through the use of computer programs or controlling robots so that they can be controlled remotely via the Internet on Thing. Implementation of Educational Robotics in the classroom can help students understand learning material related to the field of science and technology and can practice skills such as programming skills and computational skills, communication, and collaboration skills, problem-solving, and creative thinking. The use of the Educational Robotics type is customized at the needs of students such as the class level and the difficulty level of the material to learn science and technology learning material. In the future, Educational Robotics can be applied at all levels of education so that students are ready to face challenges and change that lead to full automation and digitization.

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