IOJPE

ISSN: 1300 – 915X
www.iojpe.org

International Online Journal of Primary Education 2023, volume 12, issue 1

PEDAGOGICAL CLASSIFICATION OF EDUCATIONAL ROBOTS IN PRE-SCHOOL TEACHING

Muhammed Murat GÜMÜŞ
Lecturer, Amasya University, Institute of Science, Amasya, Türkiye
ORCID: https://orcid.org/0000-0002-3677-8928
muhammed.gumus@amasya.edu.tr

Osman KAYHAN
Lecturer, Amasya University, Institute of Science, Amasya, Türkiye
ORCID: https://orcid.org/0000-0001-5407-6375
osman.kayhan@amasya.edu.tr

Özgen KORKMAZ
Ph.D., Professor, Amasya University, Department of Computer Engineering, Amasya, Türkiye
ORCID: https://orcid.org/0000-0003-4359-5692
ozgenkorkmaz@gmail.com

Halis ALTUN
Ph.D., Professor, Istanbul Health and Technology University,
Department of Software Engineering, İstanbul, Türkiye
ORCID: https://orcid.org/0000-0002-2126-8757
halis.altun@istun.edu.tr

Nihat YILMAZ
Ph.D., Selçuk University, HANARGE Industrial Electronics Information Systems Ltd. Konya, Türkiye
ORCID: https://orcid.org/0000-0003-1340-9270
nihatyilmaz@hanarge.com

Received: September 19, 2022 **Accepted:** January 22, 2023 **Published:** March 31, 2023

Suggested Citation:
Gümüş, M. M., Kayhan, O., Korkmaz, Ö., Altun, H., & Yılmaz, N. (2023). Pedagogical classification of educational robots in pre-school teaching. *International Online Journal of Primary Education (IOJPE), 12*(1), 25-41. https://doi.org/10.55020/iojpe.1177237

Abstract

This study aims to create a rubric based on the pedagogical properties of educational robots for pre-school students and determine the compliance level with educational robot sets. In this sense, the study is considered a first and significant step toward selecting robots based on pedagogical-driven factors. For this aim, a mixed-method research design was employed. A qualitative method was used to create the rubric items, and the rubric development was also supported through a quantitative process by including expert opinions and ensuring content validity. Furthermore, a descriptive survey model, one of the quantitative designs, was used to examine the suitability of educational robots for the pre-school education level. As an outcome of this study, a rubric of four dimensions with 28 items related to the pedagogical features of educational robots in pre-school was created. Furthermore, widely used educational robots at the pre-school level, such as Kidoboto, Lego Wedo, Mbot, Lego Spike, Lego Ev3, and Matatalab, were evaluated by experts using the created rubric.

Keywords: Educational robots, 21st-century skills, rubric, pre-school student.

INTRODUCTION

We live in an age where we expect students to acquire 21st-century skills and develop higher-order thinking skills. At this age, students are expected to have skills such as being adapted to changes in society, using technology effectively and correctly, finding the information required quickly from complex information stacks, and evaluating data obtained effectively by analyzing and using the information in their daily lives (Tuğluk & Özkan, 2019). In the literature, various definitions and classifications are available for the 21st-century required skills (Assessment and Teaching of 21st-century Skills Framework [ATC21S], 2010; International Society for Technology in Education National Education Technology Standards [ISTE], 2019; Ministry of National Education [MONE], 2013; Partnership for 21st-century Learning [P21], 2019). Among these, the classification made by the Partnership for 21st-century learning (2019) is generally accepted. It is observable that most of the studies conducted recently are based on this classification (Kalemkuş & Bulut Özek, 2021; Yıldırım & Ortak, 2021; Dinler et al., 2021). 21st-century skills are grouped under three main headings by P21 (2019): learning and innovation, information media and technology, and life career skills. (P21, 2019). The P21 platform categorizes 21st-century skills, as shown in Table 1.

Table 1. 21st-century skills of the P21 platform

Learning and Innovation Skills	Life and Career Skills	Information, Media, and Technology Skills
Creativity and Innovation	Flexibility and Adaptability	Information and Media Literacy
Critical Thinking and Problem-Solving	Initiative and Self-Direction	
Communication	Social and Cross-Cultural Skills	
Collaboration	Productivity and Accountability	
	Leadership and Responsibility	

Learning and innovation skills, life and career skills, information, media and technology skills are the ones that every individual should acquire to get prepared well for the even-getting more complex daily life and work environments of the 21st century (Yıldırım & Ortak, 2021). For individuals to use 21st-century skills effectively, acquiring these skills should start as early as pre-school (Çetin & Çetin, 2021). In early childhood, children develop skills such as logical thinking, estimation, hypotheses, and analysis (Katz, 2010). Therefore, the activities to foster students in acquiring these skills in early childhood would help develop their potential and increase their readiness for upcoming educational stages. (Polat & Bardak, 2019). In line with this trend, the Ministry of National Education (2013) emphasized the importance of bringing 21st-century skills to children in the pre-school education program and prepared most of the acquisitions by considering these skills. Different kinds of approaches are in use for students to acquire these skills. Some of them are based on using educational robots and coding education (Khodabandelou & Alhoqani, 2022; Yang et al., 2022; Usengül & Bahçeci, 2020; Sáez-López et al., 2019; Korkmaz, 2018).

Educational robots have been used as a part of educational studies through various activities. For example, educational robots have been used in activities aimed at increasing the academic achievements and the attitudes of students, such as programming, problem-solving, computational thinking, STEM, and logical-mathematical thinking skills (Kaya et al., 2020; Korkmaz et al., 2019; Memiş, 2020; Paucar-Curasma et al., 2022; Yang et al., 2022; Marzano & Zorzi, 2022). Some features of the educational robots, such as Lego Wedo, Lego Spike, Lego EV3, Lego Boost, Mbot, and Matatalab, which are used in these studies, are given in Table 2.

Examining Table 2 reveals that there are various kinds of educational robots to use, which show similar and different structures. Using these robots, it is aimed to gain other skills for multiple activities. In the literature, McAllister and Glidden (2022) used Lego Spike sets to teach robotic concepts and evaluated the teaching of robotics concepts with students' teachers. In another study, Tweedale (2022) proposed using Lego EV3 sets in teaching robotic concepts. Khodabandelou and Alhoqani (2022) have conducted studies using Lego Wedo educational robots for primary school students to acquire computational thinking skills and adopt robot technology. In yet another study, Usengül and Bahçeci (2020) investigated the effect of the Lego Wedo 2.0 educational robot on students' academic achievement, attitudes, and computational thinking skills. However, Veselovská and Mayerová (2017) developed various activities with the Lego Wedo robot to develop a secondary school curriculum to improve students' knowledge, skills, and abilities. Yang et al. (2022) investigated the implications of Matatalab, another educational robot, on the education of primary and pre-school students.

Table 2. Features of educational robots

Educational Robots							
Features	**Lego EV3**	**Lego Spike**	**Lego Wedo**	**Lego Boost**	**Matatalab**	**MBot**	**Kidoboto**
Robot Type	Demounted	Demounted	Demounted	Demounted	mounted	mounted	mounted
Coding Type	Codable with various methods	Codable with various methods	Codable with various methods	Codable with various methods	Coding with blocks	Codable with various methods	
Interface	Interface available	Interface available	Interface available	Interface available	No interface available	Interface available	No interface available
Number of pieces	The number of pieces was 541	The number of pieces was 528	The number of pieces is 280	The number of pieces was 847	Single Piece	Single Piece	Single Piece
Package content	Motor and sensors	Motor and sensors	Motor and sensors	Application Booklets and sensors	Control cards, blocks, obstacles, flags, maps, and booklets	Remote control and mission maps	Applicati on booklets and mission map

Moreover, Korkmaz (2018) observed the effect of programming with the Lego EV3 robot on students' problem-solving and logical-mathematical thinking skills. Veselovská, Mayerová (2017) have developed various activities with the Lego Wedo robot to improve students' knowledge, skills, and abilities in their work on developing the secondary school curriculum. Yang et al. (2022) investigated the implications of educating primary and pre-school students with Matatalab. In another study, Korkmaz (2018) observed the effect of programming with the Lego EV3 robot on students' problem-solving and logical-mathematical thinking skills. However, Sáez-López et al. (2019) investigated the impact of using the Mbot robot on the mathematical thinking skills of primary school students. Turkish engineers developed the Kido-Boto robot as a Montesorri and STEM material for school students. Before the Kidoboto robot was included in the study, it was examined by field experts and researchers who thought it could be included. In line with the opinions of experts and researchers, it has been predicted that the kidoboto robot can easily teach coding to pre-school students.

Additionally, it was stated that with this robot, students could code with a concrete programming approach and stories and games prepared for this without being connected to the screen. In this context, it was thought that the Kidoboto robot could help students improve their communication and physical development, social and emotional skills, and counting and problem-solving skills. It also helps achieve gains in communication skills, physical development, social and emotional skills, counting skills, and problem-solving and logical reasoning. All these studies focused on similar skills and acquisitions with educational robots that provide various activities. Educational robots have been observed to be effective in developing students' programming, problem-solving, computational thinking, STEM, and logical-mathematical thinking skills and in increasing students' academic achievement and attitudes (Khodabandelou & Alhoqani, 2022; Usengül & Bahçeci, 2020; Korkmaz, 2018; Sáez-López et al., 2019) and educational robot designs have been developed to contribute to this line of trends. Therefore, it is possible to claim that educational robots are central to pedagogy.

It is thought that pedagogical features for educational robots are central to determine the effectiveness of approaches, ensure the progress of the learning process working correctly, and make the incorporation of the educational robot in the educational process meaningful (Tang, Tung, & Cheng, 2020). However, it has been observed that the studies on educational robots do not focus properly on pedagogical approaches and theoretical frameworks and that the studies lack pedagogical practices, and it is often emphasized that pedagogical approaches and theoretical perspectives are to be incorporated in educational robot studies (Xia & Zhong, 2018; Serholt, 2018; Schina, Esteve-González & Usart, 2021; Atman Uslu, Öztüre Yavuz & Koçak Usluel, 2022). Therefore, it can be said that studies aimed at determining the pedagogical characteristics of educational robots will fill a gap in the literature. For this reason, it is thought essential to examine the classifications of educational robots in the market to match educational robots to students' achievements in educational processes and to determine their pedagogy of educational robots. Some studies highlight these requirements for classifying educational robots (O'Brien, 2020; Pei & Nie, 2018; Kocaçil, 2020).

O'Brien (2020) classified educational robots by considering the physical design, coding, and training method in his study. His classification is shown in Figure 1.

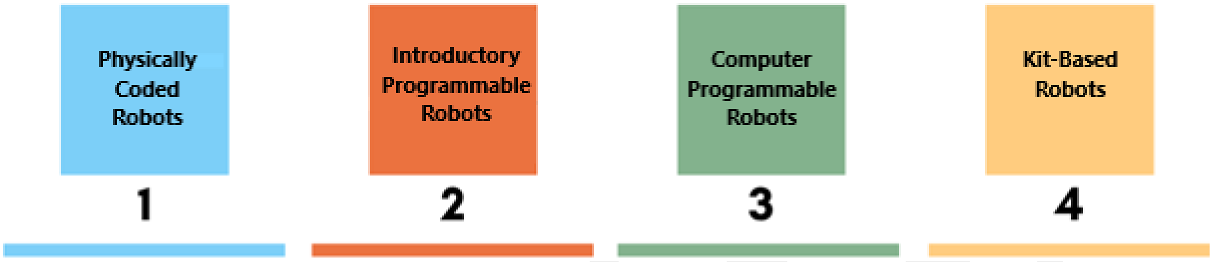

Figure 1. O'Brien's educational robot classification

As shown in Figure 1, O'Brien (2020) divided educational robots into four groups: physically coded robots, basic-level programmable robots, computer-programmable robots, and KIT-based robots. Physically coded robots are mounted robots. They are programmable with buttons and are primarily prepared for pre-school students. A learning process can be provided using game-based activities with these robots. Therefore, structured tasks and activities can be designed. Examples of robots that can also teach basic skills are the Kidoboto, Bee-Bot Robot, Cubetto Robot, Code-a Pillar Robot, and Thymio Robot. Robots programmed at the entry level are mounted robots that can be coded with a tablet, smartphone, and remote control and are intended for primary school students. A learning path can be provided with these robots by using game-based activities. Therefore, structured tasks and activities can be designed with these robots. Bootley Robot can be given as an example of a robot that can be used to teach basic writing and coding. Robots that can be programmed with a computer are assembled robots. It allows for block-based or text-based coding and is intended for elementary and secondary school students. These robots, structured tasks, and activities can be designed. This can provide a programmatic learning path using different sensors. It also allows complex and creative coding. Examples of these robots are Edison Robot, Sphero Bolt, and Mbot. Kit-based robots, unlike other robots, are unmounted. Students are expected to mount and program the robots by themselves. It allows block-based or text-based coding. Structured tasks and activities can be designed with robots for high school students. Robots that enable programming-based learning by using the electronics and engineering knowledge of the users also help complex and creative coding by using problem-solving skills. Examples of these robots are LEGO Mindstorms EV3 and VEX.

In a study, Pei and Nie (2018) classified educational robots by considering the functions of the robots and user knowledge. His type is shown in Figure 2.

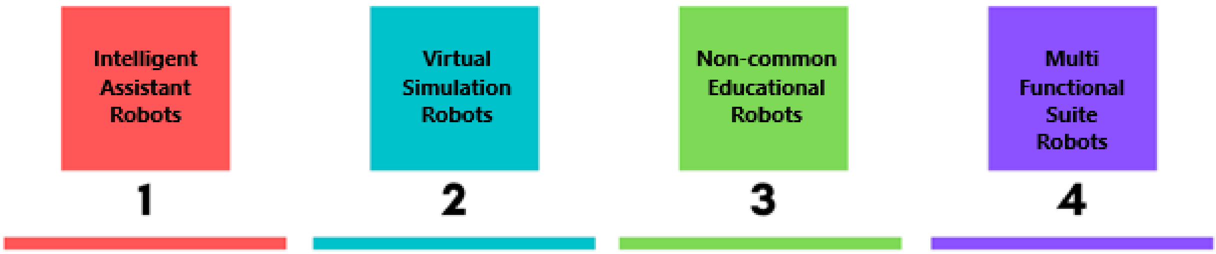

Figure 2. Pei and Nie's educational robot classification

As shown in Figure 2, Pei and Nie (2018) divided educational robots into four groups: intelligent assistant robots, virtual simulation robots, non-common educational robots, and multi-functional suite robots. Intelligent assistant robots are speech systems that can use natural language technology. Thus, it is integrated with artificial intelligence. It also performs semantic recognition, emotional awareness, data mining, and analysis. An example of these robots is the Jill robot developed by IBM. Virtual simulation robots perform simulation and interaction tasks running on computers. Therefore, 3D graphics and simulation are in use. These robots have been used to develop students' practical and innovative abilities and used in experimental studies or competitions. Microsoft Robotics Studio and iRobotQ 3D are examples of these robots, to name a few. Uncommon educational robots, however, are intended for special groups such as special needs education students. These robots can imitate facial and muscle movements or body behavior. It can also improve the emotional and social abilities of students with autism. Smart toys for preschoolers, medical education robots for medical students, and language training robots for language learning are examples of these educational robots. Finally, multi-functional suite robots develop students' knowledge and skills. They can be freely assembled according to the teaching requirement, and they are suitable to be used by pre-school pupils to seniors. Different modules can be combined to complete various tasks and are ideal for STEM activities. Examples of these robots are the LEGO Kits and Ability-Storm.

However, Kocaçil (2020) stated in his study that Parallax Robotics Sets, Fischertechnik Sets, Lego Mindstorms Sets, Makeblock Sets, VEX IQ Platform Sets, and Robotic Sets could be used as educational robots. To this end, he classified the educational robots according to their grade levels. He divided them into three groups a pre-school-primary school group, a middle school group, and a high school group. Educational robots classified in the preschool-primary school group are Cubetto, Cody Rocky, Bee-Bot, Clementoni, and LEGO Wedo 2.0; in the middle school groups are Makeblock Mbot, Makeblock mbot ranger, Makeblock ultimate, Robotis Dream, and LEGO Mindstorms EV3, and in the high school groups are LEGO Mindstorms EV3, VEX IQ, and Arduino UNO kits.

However, Bravo, González, and González (2017) divided the programming languages used in educational robots into five groups as such as general programming languages, particular programming languages, visual programming languages, concrete programming languages, and text and visual programming languages. C/C++, Java, and Phyton languages are examples of available programming languages. Examples of specific programming languages are ROBOTC (LEGO Mindstorms and VEX Robotics), Aseba Studio (Thymio ROBOT), Robot Mesh Studio (VEX), and LeJOS (LEGO Mindstorms). In addition, however, Scratch, MBlock, Lego Mindstorms EV3, NXT-G, Built-in Studio for WeDo 2.0, PicoBlocks, Aseba Studio, Microsoft VPL, MySkit, Choregaphe are listed as examples of visual programming languages.

However, the tangible programming languages Cubetto, Kibo, Project Bloks, CHERP, Tern, Playte, PROTEAS, Algoblocks, and Robo-Bloklar are given as examples. Finally, Blockly, Tickle, The Coder MIP App, R+ Task 2.0, EasyC, Scratch, Enchanting, Ardublock, MiniBloq, Modkit, and Alice are shown as examples of text-based and visual programming languages. In another study, Fessakis, Gouli, and Mavroudi (2013) stated why the educational robots classified in their research should be chosen for children. They indicated that software environments such as Scratch, Stagecast Creator, Squeak Etoys, Microworlds, and Toon Talk are helpful and straightforward for primary school students. The features of these programs that they think are suitable for children are listed as follows: having simple symbols and syntax, using drag-and-drop methods, having remarkable visual designs and characters, instantly viewing whether the codes are working, being away from traditional education, and providing game-based learning. However, when the relevant research is examined, it is seen that the classification of educational robots is not evaluated primarily in terms of pedagogical features. Additionally, although it is seen that the characteristics and types of educational robots have been made generally, it is often emphasized that there is no focus on their pedagogical features. There is a lack of explanations of pedagogical features.

In this context, this study attempts to determine the pedagogical characteristics of educational robots by examining studies on 21st-century skills and educational robots, with special focus to create a rubric that includes these features. The second part of the study aims to investigate the suitability of the educational robot sets, which are frequently used, for the pre-school education level by using the rubric obtained.

In this sense, this study focuses on the pedagogical features of educational robots, unlike previous studies on educational robots. Therefore, it is thought that it will contribute to the literature on the pedagogical evaluation of educational robots based on 21st-century skills. Additionally, it is believed that it will guide teachers in using educational robots suitable for the level of pre-school students. However, it is thought that the rubric developed for future research will contribute to future research in determining whether the newly designed educational robots are suitable for the level of pre-school students and choosing the prominent features of different educational robots.

Research Problem

1. What are the pedagogical features of educational robots that are widely used in the literature?

2. Is the rubric tool developed to evaluate the pedagogical characteristics of educational robots valid and reliable?

METHOD

This study was conducted in two stages. In the first stage, the rubric was developed, and in the second stage, the suitability of the developed rubric and educational robots for the pre-school education level was evaluated. A mixed-method research design was employed in this study. A qualitative method was used to create the rubric items, and the rubric development was also supported through a quantitative process by including expert opinions and ensuring content validity. Furthermore, a descriptive survey model, one of the quantitative designs, was used to examine the suitability of educational robots for the pre-school education level.

Study Group

In this study, the study group consists of five academicians, two of whom work in the field of Educational Sciences, one in the area of Computer Technologies, one in the field of Computer and Instructional Technologies Education, and one in the field of Software Engineering. They are experts in developing rubric tools and have previous experience with educational robots. Furthermore, four experts, two Computer and Instructional Technologies Education teachers, and two field experts, who are experienced in robotics, are involved in the evaluation of educational robots. However, a total of seven educational robots, namely, Kidoboto, Lego EV3, Mbot, Lego Spike, Lego Wedo, Matatalab, and Lego Boost, were included in the evaluation.

Development of Data Collection Tool

The literature has been reviewed to create rubric items, and the classification of educational robots and the achievements of pre-school students' 21st-century skills have been examined. The findings show that different definitions and categories are available at the national and international levels (ATC21S, 2010; ISTE, 2019; MONE, 2013; P21, 2019). From these studies, the P21 platform has gathered 21st-century skills under the headings of learning and innovation skills, life and career skills, information, media, and technology skills. Using these definitions and classifications, 21st-century skills were discussed on different topics, and achievements have been determined (Kalemkuş & Bulut Özek, 2021; Yıldırım & Ortak, 2021; Dinler et al., 2021) A 24-item rubric is created considering the findings of the literature review. The designed rubric items are e-mailed as forms to five experts in the field to determine the structural suitability and intelligibility level. Opinions have been made about the rubric items created by these experts. Experts have been asked to evaluate rubric items using options such as "appropriate, inappropriate, and correctable" to assess them. To identify the items that are not suitable and need to be corrected, the section "Your warning/suggestion regarding the item" was created, and they were asked to explain in the section. Additionally, apart from the listed items in the form, the "Item Suggestions" section was created for the items the experts believe should be added. Table 3 contains some information about expert opinions.

Table 3. Examples of expert opinions on rubric substances

Expert	Rubric Item	Evaluation	Explanation
Expert 1	It should allow for different activities/tasks.	Improvable.	What kind of these different activities?
Expert 2	It should allow for different activities/tasks.	Improvable.	This feature requires the robot's complex design, which may not be particularly suitable for preschoolers. But it is necessary for high-level users.
Expert 3	Error codes/messages are displayed on the interface.	Improvable.	On the interface or the screen? The phrase "on screen" seemed to be too much.
Expert 4	The interface features remarkable visual design and characteristics.	Improvable.	What if the visual designs are eye-catching but lack character?
Expert 5	The settings of the robot can be adjusted in different ways.	Improvable.	This was a bit of an ambiguous statement. Perhaps it will be clearer as follows: "It can adjust the robot's settings according to its purpose."

After obtaining the experts' opinions, the rubric items have been re-examined, and the necessary arrangements have been made. The items that need to be removed from the rubric items have been removed, items deemed appropriate to be added have been added, and items that need to be edited have been updated in line with expert opinion. As a result, a pedagogical rubric is obtained for educational robots with 32 items consisting of 0–4 points.

During the creation of the rubric, to evaluate the harmony of the experts, they were asked to assess the final version of the rubric in the range of "1-Appropriate, 2-Adjustable, 3-Not Appropriate." Although according to the compliance assessment of the experts, adjustments were made in items 1 and 6, item 30 was removed from the rubric. Therefore, 31 items were evaluated. According to Miles and Huberman (1994), the percentage of consensus is calculated as follows.

Percentage of Consensus = Consensus / (Consensus + Disagreement) x 100

In this study, the calculation of the consensus percentages was made by the researcher for each question separately. Accordingly, for items 1, 2, 6, 7.9, 10, 11, 12, 17, 18, 20, 24, 27, and 29, the consensus percentage is 80.00%, and the consensus percentage in the other items is calculated as 100.00%. The consensus percentage for all items was found to be 91.33%. If the consensus rate between experts is higher than 70%, it can be said that their coding is reliable (Creswell, 2017).

It has been determined that the rubric items created with expert opinions are acceptable to evaluate educational robots fairly. Additionally, rubric items were divided into factors according to expert opinions, twenty-first-century features, and features of educational robots. An expert view was sought for the factors' terminology, which was taken from the statements in the items. In this direction, four elements have been created. Accordingly, items 3, 12, 23, 27, 28, 60, and 31 are named "Flexibility and Adaptation" (total number of items n=7), items 1, 5, 11, and 26 are designated as "Technological Integration" (total number of items n=4), articles 4, 8, 9, 10, 13, 14, 15, 16, 17, 18, 20, 24, 25, and 29 are named as "Support to Learning" (total number of items n=14) and articles 6, 7, 19, 21, 22, and 2 are called "Educational Design" (total number of items n=6). The rubric given in the final form is presented in Annex 1.

Data Analysis

With the developed rubric, the educational robots, Kidoboto, Lego EV3, Mbot, Lego Spike, Lego Wedo, Matatalab, and Lego Boost, were evaluated between 0 and 3 points by four experts. The data obtained from the four experts have been averaged separately for each robot. However, each factor was averaged and examined on a factor basis. In this direction, educational robots were compared according to the averages obtained. Additionally, the consensus percentage (Consensus / (Consensus + Disagreement) x

100) was calculated for the rate of consensus of expert opinions when developing the rubric and for calculating the percentage of harmony of the responses given by the experts in the evaluation of the rubric and robots. Accordingly, the rates of consensus of the answers provided by the experts in the assessment of the robots with the rubric are given in Table 4.

Table 4. Percentage of consensus according to expert evaluations of educational robots

Item No	Educational Robots						
	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
	Consensus Percentage						
1	75	100	40	50	75	100	50
2	100	75	50	75	75	100	75
3	75	100	100	100	100	75	75
4	75	75	75	100	100	75	75
5	100	100	50	75	100	75	75
6	75	50	50	50	75	75	75
7	75	40	40	40	75	40	75
8	75	50	40	50	100	75	75
9	100	50	100	100	75	40	100
10	100	50	75	75	100	40	50
11	100	75	75	75	40	40	40
12	100	40	40	40	75	75	50
13	75	75	75	50	100	75	50
14	75	50	75	50	75	50	75
15	40	75	50	75	100	75	50
16	40	100	50	75	50	50	75
17	75	40	75	40	0	75	75
18	100	100	75	75	50	40	75
19	75	75	40	75	75	40	75
20	100	75	100	75	75	75	100
21	100	50	75	50	50	40	75
22	75	100	100	40	40	40	50
23	40	50	40	50	75	50	75
24	75	75	100	75	75	50	75
25	40	75	75	40	40	40	75
26	100	75	50	100	100	100	75
27	75	50	75	75	75	75	75
28	40	75	50	50	75	75	75
29	100	75	75	75	100	40	75
30	75	100	50	50	100	40	40
31	50	50	50	40	100	40	75

When the consensus percentages for the Kidoboto educational robot are analyzed in Table 4, there is 100% consensus for items 2,5,9,10,11,12,18,20,21,26, and 29; while for items 1,3,4, 6,7,8,13,14,17,19,22,24,27, and 30, it is 75%; and for item 31, it is 50%, and for items 15,16,23,25 and 28 it is 40%. When the consensus percentages for the Lego EV3 educational robot are examined, there is 100% agreement for items 1,3,5,16,18,22, and 30; while for items 2,4,11,1315,19,20,24,25,26, 28, and 29, it is 75%; and for items 6,8,9,10,14,21,23,27 and 31 it is 50%; there is 40% consensus for items 7, 12, and 17. When the consensus percentages for the Mbot educational robot are examined, it is 100% for items 3,9,20,22, and 24; for items 4,10,11,13,14,17,18, 21,25,27, and 29, it is 75%; and it is 50% for items 2,5,6,15,16,28,30 and 31; there is 40% consensus for items 1,7,8,12,19 and 23. When the consensus percentages for the Lego Spike educational robot are examined, there is 100% consensus in items 3,4,9 and 26, while for items 2,5,10,11,15,16,18,19,20,24,27, and 29, it is 75%; it is 50% for items 1,6,8,13,14,21,23,28, and 30; there is 40% consensus for items 7,12,17,22,25 and 31. When the consensus percentages for the Lego Wedo educational robot are examined, there is 100% agreement in items 3,4,5,8,10,13,15,26,29,30, and 31; while for items 1,2,6,7,9,12,14,19,20,23,24,27, and 28, it is 75%; it is 50% for items 16, 18, and 21; it is 40% consensus for items 11.22 and 25 and 0% for item 17. When the consensus percentages for the Matatalab educational robot are examined, there is 100%

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ISSN: 1300 – 915X
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International Online Journal of Primary Education 2023, volume 12, issue 1

consensus in items 1,2 and 26, while it is 75% for items 3,4,5,6,8,12,13,1517,20,27, and 28; it is 50% for items 14, 16, 23, and 24; there is 40% consensus for items 7,9,10,11,18,19,21,22,25,29,30, and 31. Finally, when the consensus percentages for the Lego Boost educational robot are examined, there is 100% consensus in items 9 and 21, while for items 2,3,4,5,6,7,8,14,16,17,18,19,21, 23,24,25,26,27,28,29, and 31, it is 75%; for the items 1,10,12,13,15, and 22 it is 50%, and it is 40% for items 11 and 30.

According to the evaluations by the experts, if the consensus rate is higher than %70, it can be said that coding is reliable (Creswell, 2017; Miles & Huberman, 1994). However, when the consensus percentages of the experts are examined separately for each educational robot, it is seen that items show a low consensus rate below 70%. It is thought that this is because the experts evaluating the items have different backgrounds in educational robots. Therefore, the experts' observation of educational robots is based on other activities and examples while assessing.

FINDINGS

The average scores for the educational robots, in line with expert opinions, according to the Technological Instructional Design factor and related items, are shown in Table 5.

Table 5. Average scores of educational robots by technological integration factor

I	Item	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
1	Settings that affect the characteristic behavior of the robot can be adjusted.	0	3	1.7	2.5	2.7	0	2
11	It is possible to use other technologies (smartphones, 3D printers, etc.) to conduct various activities.	0	2.2	2.5	2.2	1.7	1	2
26	It is controllable by various technologies (Tablet, computer, remote control, etc.).	0	2.7	2.5	3	3	0	2
5	The drag-and-drop method was used at the interface.	0	3	2.5	2.7	3	.7	3
Technological Integration		0	2.8	2.3	2.6	2.6	.4	2.3

When Table 5 is examined, according to the item (M=1: "settings that affect the characteristic behavior of the robot can be adjusted."), the educational robot with the highest score was Lego Spike, and the educational robot with the lowest score was Kidoboto and Matatalab. According to the item (M=11: "It is possible to use other technologies (smartphones, 3D printers, etc.) to conduct various activities."), the educational robot with the highest score is Mbot, and the educational robot with the lowest score is Kidoboto. According to the item (M=26: "It is controllable by various technologies (Tablet, computer, remote control, etc.)."), the educational robot with the highest score was Lego EV3, and the educational robot with the lowest score was Kidoboto and Matatalab. According to the item (M=5: "The drag-and-drop method is used in the interface."), the educational robot with the highest score was Lego Spike, and the educational robot with the lowest score was Kidoboto. Finally, according to the technology integration factor average scores, it can be said that the robot with the highest score was Lego Ev3, and the educational robot with the lowest score was the Kidoboto robot. Additionally, when educational robots are evaluated according to the Technological Integration factor, the use of Lego EV3, Lego Wedo, Lego Spike, Lego Boost, and Mbot robots seems to be more suitable in pre-school education regarding the scores obtained for the items as shown in Table 5. The average scores of educational robots, in line with expert opinions, according to the Instructional Design factor and related items, are shown in Table 6.

IOJPE

ISSN: 1300 – 915X
www.iojpe.org

International Online Journal of Primary Education 2023, volume 12, issue 1

Table 6. Average scores of educational robots by educational design factors

I	Item	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
2	Error codes or messages are displayed at the interface.	0	.2	1.5	.2	.2	0	0
6	The interface contains appropriate visual designs.	.2	2.5	2.5	2.5	2.7	.5	3
7	There are remarkable visual characters at the interface.	.2	1.7	2.2	2	2.7	1,2	3
19	It checks whether the codes work properly for the purpose or not.	.2	.2	1,7	.2	.2	.7	0
21	The visual design of the robot is interesting.	1	2.5	2.2	2.5	2.5	2	2
22	The visual design of the interface is interesting.	.2	2	2	2,2	2	1.2	2
Educational Design		Educational Design	1.5	2.0	1.6	1.8	1.0	1.7

An examination of Table 6 reveals that according to the item (M=2), the educational robot with the highest score is Mbot and the educational robot with the lowest score is Kidoboto and Matatalab. According to the item (M = 6), the educational robot with the highest score is Lego Wedo, and the educational robot with the lowest score is Kidoboto. According to the item (M = 7), the educational robot with the highest score was Lego Wedo, and the educational robot with the lowest score was Kidoboto. According to the item (M=19), the educational robot with the highest score is Mbot, and the educational robot with the lowest score is Lego Boost. According to the item (M = 21), the educational robot with the highest score was Lego Wedo, Lego EV3, and Lego Spike, and the educational robot with the lowest score was Kidoboto. According to the item (M=22), the educational robot with the highest score is Lego Spike, and the educational robot with the lowest score is Kidoboto. Generally, it can be said that the robot with the highest score according to the educational design average scores is the Mbot and the educational robot with the lowest score is the Kidoboto robot. Also, according to the educational design factor average score, the robot with the highest score was Lego Ev3, and the educational robot with the lowest score was the Kidoboto robot. Additionally, according to the Educational Design factor, the education robots, Lego EV3, Lego Wedo, Lego Spike, Lego Boost, and Mbot robots are more suitable in terms of showing error codes on the interface, finding appropriate visual designs, finding remarkable visual characters, checking codes and making the visual design of the robot and interface interesting, for educating pre-school students. The average scores of educational robots, in line with expert opinions, according to the Flexibility and Adaptation factor and its related items, are shown in Table 7.

Table 7. Average scores of educational robots on flexibility and adaptability factors

I	Item	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
3	The robot can be easily coded by illiterate students thanks to blocks of simple symbols.	1.5	0	0	0	2	2	0
12	Activities with educational robots are suitable to be associated with real life.	1	2.2	2	2	2.2	.7	2
23	Piece assembly processes are suitable for student level.	.7	1.5	1.2	1.5	1.7	2.5	1
27	Existing parts can be used for different purposes.	.2	2.5	1.2	2.7	2.7	.2	2
28	It provides an opportunity to study and learn on their own.	1	1.7	1.5	1	1.7	2.2	1

Table 7 (Continued). Average scores of educational robots on flexibility and adaptability factors

I	Item	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
30	The programming interface is designed in a way that the age groups can easily understand.	.5	1	.5	1	2	1.2	1
31	The activities offered by the educational robot set are compatible with the pre-school program.	1.5	.5	.5	.7	2	2	0
Flexibility and Adaptation		Flexibility and Adaptation	1.4	1.0	1.3	2.1	1.6	1.0

When Table 7 is examined, according to the item (M=3 “The robot can be easily coded by illiterate students thanks to blocks consisting of simple symbols”), the educational robot with the highest scores is Lego Wedo, Matatalab, and the educational robot with the lowest scores Lego EV3, Mbot, Lego Spike, and Lego Boost. According to the item (M=12 “The activities with the educational robot are convenient to be associated with real life”), the educational robot with the highest score is Lego EV3, Lego Wedo, and the educational robot with the lowest score is Kidoboto. According to the item (M=23 “Part assembly operations are suitable for student level.”), the educational robot with the highest score is Matatalab, and the educational robot with the lowest score is Kidoboto. According to the item (M=27 “Existing parts can be used for different purposes.”), the educational robot with the highest score is Lego Spike and Lego Wedo, and the educational robot with the lowest score is Kidoboto and Matatalab. According to the item (M=28: “It provides the opportunity to self-study and learn.”), the educational robot with the highest score is Matatalab, and the educational robot with the lowest score is Kidoboto Lego Spike and Lego Boost. According to the item (M=30: “The programming interface is designed in such a way that the age group can easily understand it.”), the educational robot with the highest score was Lego Wedo, and the educational robot with the lowest score was Kidoboto. According to the item (M=31: “The activities offered by the educational robot set are compatible with the pre-school program.”), the educational robot with the highest score is Matatalab, and Lego Wedo and the educational robot with the lowest score is Lego Boost. Generally, it can be said that the robot with the highest score in terms of flexibility and adaptability factor averages is Lego Wedo, and the educational robot with the lowest score is the Kidoboto robot. Finally, it can be said that the robot with the highest score in terms of flexibility and adaptability factor average scores is Lego Ev3, and the educational robot with the lowest score is the Kidoboto robot. Additionally, when educational robots are evaluated according to the Flexibility and Adaptation factor due to their features such as being efficiently coded by illiterate students, associating activities with real life, the appropriateness of part joining processes, the availability of parts for different purposes, the presentation of self-study and learning opportunities, the suitability of the programming interface and activities in terms of the usefulness of the programming interface and activities Lego EV3, Lego Wedo, Lego Spike, and Matatalab robots are more appropriate for educating pre-school students. The average scores of educational robots, in line with expert opinions, according to the Support to Learning factor and related items, are shown in Table 8.

Table 8. Average scores of educational robots according to the support to learning factors

I	Item	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
24	The robot includes voice instructions.	.2	1.5	0	.5	.2	.5	2
25	The robot includes visual instructions.	.7	2.2	.5	2.2	1.7	2	2
29	The educational robot allows different robot designs that can perform the same function.	0	2.5	1.7	2.7	3	1.2	2

Table 8 (Continued). Average scores of educational robots according to the support to learning factors

I	Item	Kidoboto	Lego EV3	MBot	Lego Spike	Lego Wedo	Matatalab	Lego Boost
8	The interface includes visual instructions.	.7	2.5	1.2	2.5	3	.7	3
9	The interface includes voice instructions.	0	.5	0	0	.2	.7	0
10	It provides opportunities for various activities/tasks.	1	2.5	2.7	2.7	3	1.7	2
4	The educational robot kit provides examples of these activities.	.7	2.7	2.7	3	3	2.7	3
13	Develops creativity skills.	1.2	2.7	2.2	2.5	3	2.2	2
14	The develops problem solving skills.	1.2	2.5	2.2	2.5	2.7	2.5	2
15	Develops algorithmic thinking skills.	1	2.7	2.5	2.7	3	2.7	2
16	Develops psychomotor skills.	1	3	1.5	2.2	2.5	1.5	3
17	Develops collaborative working skills.	.2	1.7	1.2	1.7	1.5	1.2	2
18	It offers several methods for reviewing errors.	0	0	.7	.2	.5	1	0
20	Give appropriate feedback on the tasks performed.	0	.2	0	0,5	.5	0,2	0
Support to Learning		Support to Learning	2.0	1.4	1.9	2.0	1.5	1.8

When Table 8 is examined, according to the item (M=24: "The robot includes voice instructions."), the educational robot with the highest score is Lego Boost, and the educational robot with the lowest score is Mbot. According to the item (M=25: "The robot includes visual instructions."), the educational robot with the highest score is Lego Spike and Lego EV3, and the educational robot with the lowest score is Mbot. According to the item (M=29: "The educational robot makes it possible to design different robots that can perform the same function."), the educational robot with the highest score is Lego Spike, and the educational robot with the lowest score is Kidoboto. According to the item (M=8:" The interface contains visual instructions."), the educational robot with the highest score was Lego Wedo and Lego Boost, and the educational robot with the lowest score was Kidoboto. According to the item (M=9: "The interface includes voice instructions."), the educational robot with the highest score is Matatalab, and the educational robot with the lowest score is Kidoboto, MBOT, Lego Spike, and Lego Boost. According to the item (M=10: "It gives opportunity to various activities/tasks."), the educational robot with the highest score was Lego Wedo, and the educational robot with the lowest score was Kidoboto. The educational robot with the highest score according to the item (M=4: "The educational robot kit provides an example of activity.") is Lego Wedo, Lego Boost, and Lego Spike, and the educational robot with the lowest score was Kidoboto. The educational robot with the highest score according to the item (M=13: "From the services of creativity.") is Lego Wedo, and the educational robot with the lowest score is Kidoboto. The educational robot with the highest score according to the item (M=14: "Doesn't troubleshoot.") was Lego Wedo, and the educational robot with the lowest score was Kidoboto. The educational robot with the highest score according to the item (M=15: "Ignore algorithmic.") was Lego Wedo, and the educational robot with the lowest score was Kidoboto. The educational robot with the highest score according to the item (M=16: "Psycomotor design.") was Lego Boost, and the educational robot with the lowest score was Kidoboto. According to the item, the educational robot with the highest score (M=17: “Satisfied with collaborative work.”) was Lego Boost, and the educational robot with the lowest score was Kidoboto. The educational robot with the highest score according to the item (M=18: “It provides options for reviewing errors.”) was Matatalab, and the educational robot with the lowest score was Lego EV3, Lego Boost, and Kidoboto. The educational robot with the highest score according to the item (M=20: “It will be returned to us for assigned missions.”) was Lego Wedo, Lego Spike, and the educational robot with the lowest score was Kidoboto, Lego Boost, and Mbot. Finally, it can be said that the robot with the highest score in education was Lego Ev3 and the robot with the lowest score was the Kidoboto robot. Additionally, when educational robots are evaluated according to the Support to Learning factor because of their features, such as the inclusion of audio and visual instructions, enabling different robot designs, the inclusion of audio and visual instructions on its interface, allowing for constructing various activities and examples, providing opportunities for developing 21st-century and psychomotor skills, offering multiple methods for reviewing errors and providing appropriate feedback for the given tasks, it can be said that Lego EV3, Lego Wedo, Lego Spike, Lego Boost, Matatalab, and Mbot robots are more suitable for educating pre-school students.

CONCLUSION and DISCUSSION

Educational robots were evaluated in terms of pedagogical features. Considering the technological integration dimension, Lego EV3, Lego Wedo, Lego Spike, Lego Boost, and Mbot are found to be more suitable for educating pre-school students in terms of setting the characteristic behavior of the robot, using it with other technologies, controlling it through different technologies and using the drag-and-drop interface. Similarly, by examining the educational robots studies by Yang et al. (2022) and O’Brien (2020) at the pre-school level, it has been seen that educational robots with certain features, such as Matatalab and Kidoboto, have positive benefits in terms of technological integration. Additionally, this study concluded that the technological integration of Lego sets, especially Lego EV3, is more valuable than Mbot and other Lego sets. However, although educational robots such as Kidoboto and Matatalab can be used in terms of technological integration, these educational robots need to be further developed with respect to technological integration.

Considering the educational design dimension, we concluded that Lego EV3, Lego Wedo, Lego Spike, Lego Boost, and Mbot robots are suitable for educating pre-school students in terms of the robot’s characteristic behavior adjustment, use with other technologies, control via other technologies and the use of drag-and-drop interface. However, considering the educational design dimension, Lego EV3, Lego Wedo, Lego Spike, Lego Boost, and Lego EV3, Lego Wedo, Lego Spike, and Lego Boost Mbot robots are more prominent for educating pre-school students. Furthermore, when similar studies in the literature are examined, it is seen that educational robots such as Lego Wedo, Lego Spike, and Lego EV3, apart from the pre-school group, are more prominent in educational design for different levels (Usengül & Bahçeci, 2020; Tweedale, 2022; McAllister & Glidden, 2022; Korkmaz, 2018), and for the pre-school level, educational robots with features such as Matatalab come to the fore in terms of educational design (Yang et al., 2022). Additionally, this study concluded that the educational design of the Mbot set for pre-school level is more beneficial than other educational robots. However, although educational robots that do not have an interface, such as Kidoboto, can be used in educational settings, these robots need to be developed in terms of educational design.

In terms of flexibility and adaptability dimensions, Lego EV3, Lego Wedo, Lego Spike, and Matatalab robots are found to be more prominent for educating pre-school students due to having the abilities such as to be efficiently coded by illiterate students, the relevance of activities to real-life, the suitability of parts joining processes, the availability of parts for different purposes, the opportunity to self-study and learn, the suitability of the programming interface and activities. Additionally, in this study, the flexibility and adaptability of the Lego Wedo set are found to be more prominent than other educational robots. Although educational robots such as Kidoboto are usable in flexibility and adaptability, they need to be developed in terms of flexibility and adaptation. When similar studies are examined in the literature, it is seen that educational robots are not considered in terms of flexibility or adaptation dimension.

Finally, considering the learning support dimension, due to their features of having audio and visual instructions, allowing for different robot designs, containing audio and visual instructions on the interface, allowing for the production of various activities and examples, providing an opportunity for developing of twenty-first-century skills and psychomotor skills, offering multiple options for reviewing mistakes, Lego EV3, Lego Wedo, Lego Spike, Lego Boost, Matatalab, and Mbot robots are more prominent for educating pre-school students.

Examining the literature reveals that educational robots Lego EV3, Mbot, Matatalab, Lego Spike, and Lego Wedo, which are evaluated to be beyond the pre-school level, come to the fore in terms of the learning support dimension (McAllister & Glidden, 2022); Tweedale, 2022; Khodabandelou & Alhoqani, 2022; Usengül & Bahçeci, 2020; Yang et al., 2022; Korkmaz, 2018; Sáez-López et al., 2019). In this study, the Lego EV3 set stands out more than other educational robots in learning support. Although educational robots such as Kidoboto, which do not allow robot design, have limited activities, and exclude feedback for errors, can be used to support learning, there is an obvious need to be further developed in terms of learning support.

Recommends and Limitations

This study is limited to robots that are widely used in the literature and can be accessed by experts. Additionally, this study was prepared to classify educational robots used only for pre-school students. Therefore, the pedagogical classification of educational robots used for primary, secondary, and high school students can be done in future research.

Funding

This research did not receive any specific grant from the public, commercial, or not-for-profit funding agencies.

Data Availability

The data supporting this study's findings are not openly available because of [reasons of sensitivity, e.g., human data] and are available from the corresponding author upon reasonable request.

Ethics and Conflict of Interest

The authors declare that the work is written with due consideration of ethical standards. The authors declare that they have no competing interests.

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ANNEX-1

Pedagogical Characteristics of Educational Robots Rubric

Factor	Item	Features
Flexibility and Adaptation	**3**	The robot can be easily coded by illiterate students thanks to blocks of simple symbols.
	12	Activities with educational robots are suitable to be associated with real life.
	23	Piece assembly processes are suitable for student level.
	27	Existing parts can be used for different purposes.
	28	It provides the opportunity to study and learn on their own.
	30	The programming interface is designed in a way that the age group can easily understand.
	31	The activities offered by the educational robot set are compatible with the pre-school program.
Technological Integration	**1**	Settings that affect the characteristic behavior of the robot can be adjusted.
	11	It is possible to use other technologies (smartphones, 3D printers, etc.) to carry out various activities.
	26	It is controllable by various technologies (Tablet, computer, remote control, etc.).
	5	The drag-and-drop method is used in the interface.
Support to Learning	**24**	The robot includes voice instructions.
	25	The robot includes visual instructions.
	29	The educational robot allows different robot designs that can perform the same function.
	8	The interface includes visual instructions.
	9	The interface includes voice instructions.
	10	It provides opportunities for various activities/tasks.
	4	The educational robot kit provides examples of activities.
	13	Develops creativity skills.
	14	Develops problem solving skills.
	15	Develops algorithmic thinking skills.
	16	Develops psychomotor skills.
	17	Develops collaborative working skills.
	18	It offers several methods for reviewing errors.
	20	Gives appropriate feedback on the tasks performed.
Educational Design	**2**	Error codes or messages are displayed on the interface.
	6	The interface has appropriate visual designs.
	7	There are remarkable visual characters in the interface.
	19	It checks whether the codes work properly for the purpose or not.
	21	The visual design of the robot is interesting.
	22	The visual design of the interface is interesting.