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Research Article

A study on the analysis of voluntary questioning of children in the exploration of educational robots

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Abstract: The purpose of this study is to develop a STEAM education program for children using educational robots, and to analyze questions asked by children as a prior basic study. To this end, 29 children (16 boys and 13 girls) aged 3, 4 and 5 who had never experienced unplugged educational robots play were surveyed and observed, and 184 questions were extracted from video data containing a total of 300 minutes of play time. We divided the voluntary questions of children by age and analyzed them according to STEAM elements. T(Technology) was the most common STEAM element for all ages. Research results is meaningful in presenting the direction for convergent experiences and the development of computational thinking to meet the demand of the present childhood education to provide integrated education.

Keywords: children play, children software, unplugged play, educational robots, children questions, investigating questions

1. Introduction (Times New Roman 10 Bold)

We live our daily lives asking many questions to others or to ourselves. Questioning is, by a dictionary definition, "a sentence or phrase used to find out information" **(Cambridge Dictionary, 2020)**. Not only one can get the information we need by asking questions, but also we can communicate with each other and have an opportunity to think creatively **(Leeds, 2020)**. Therefore, it can be said that a questions include an interest in a subject.

As such, we acquire information through various questions in our daily lives. Likewise, children try to understand the world around them by asking questions. Children's communication skills are enhanced through the process of expressing curiosity about an object through asking questions, acquiring knowledge, listening to the answers to the questions, and asking questions again **(Cho et al., 2010; Kim, Lee, 2010)**. It is important to look at children's questions in order to understand their interests because they present what they want to know and how they relate what they know to other facts.

Therefore, it can be said that questions asked by infants include their interest and curiosity. The moment when a child's interest and curiosity are expressed the most is when he/she plays. **Krasnor and Pepler(1980)** claimed that play is about generating inner motivation, not reflecting everyday life, and expressing positive emotions, and that play has various forms and contents. **Hughes(2003)** explained that play is chosen freely, a personal enjoyment, and a focus on the process rather than outcome. **Wood(2009)** explained that scholars' opinions on play were described as internal motivation, positive emotions, symbolic behavior, representation, non-routine, active participation, behavior based od internal rules, self-control, autonomy, emphasis on process and method, and free change of subject and goal. Consequently, the definition of play by various scholars suggests that play is an activity that is caused by inner motivation and expresses. Positive emotions are expressed while plating freely.

In particular, for children, play is life itself and life is play **(Gwak, 2004).** Through play, children recognize the existence of 'me' and 'other' and learn about the world **(Lim et al., 2003)**, and develop physical and intellectual skills, and play promotes social and emotional development through interaction with peers and teachers in the play process**(Shin et al., 2002)**. Therefore, it can be seen that children explore and learn the surrounding world through play, and in order to understand the various situations that occur in play, it is necessary to examine the meaning and value of the questions that occur during play.

Since children reveal their interests and curiosity through questions, children's questions have a very important educational value, and children should be encouraged to ask questions and accepted as a starting point in the learning process **(Cho et al., 2010)**. The curriculum, which begins with the question of an child, will be more meaningful and valuable because the child becomes the subject of learning and is taught by internal motivation. Therefore, it is necessary to look at the question of children during the play process.

Our society is entering the 4th industrial revolution **(Dombrowski and Wagner, 2014)**, and upcoming future society requires the ability to respond to changes and efficiently deal with and solve complex problems. Researchers argue that is the power of convergent thinking and computational thinking. Various educational programs are being developed worldwide to enhance children's computational thinking skills as well as STEM and STEAM. Various research is being conducted, such as using computers or newly emerging educational robotics to improve computing skills, and using existing teaching tools without using computers such as CS Unplugged **(Tim Bell, 1998)**. STEAM is a combination of S(Science), T(Technology), E(Engineering), A(Arts), and M(Mathematics), and values convergent thinking and emotional experiences beyond the knowledge of each subject. STEAM education allows children to practice exploring, questioning, researching and discovering innovative technologies **(Coker, and Simon, 2014)**. These convergent thoughts and experiences need to be experienced in various ways. Early childhood is a very important time in life in which they go through expressing and sharing their thoughts and feeling in various ways, such as music, art, words, writings, and movements, and for those who were born as a digital native, unplugged educational robots are effective educational methods to provide a convergent experience in the modern era of various educational technology.

Software education is an education to enhance computational thinking skills **(Bae et al., 2016)**. **The Korean Ministry of Education (2015)** suggests unplugged play as a software education method. Unplugged play is an easy and fun way to learn the principles of computer science by utilizing materials that are easily accessible around the computer but without a computer, which is not limited to age or place **(Tim Bell, 1998)**. Therefore, unplugged play can include materials that can be easily found around people, such as colored paper, wool, and blocks, as well as traditional Korean games such as yutnori and stone-throwing.

Nevertheless, there is a burden of using computers and reluctance to use echnical jargons, such as algorithms and coding. The current trend is that computational thinking is being emphasized, so the perception should change in a way that software education can be done in an easier way.

In this study, we investigate questions asked by children that arise during natural play situation using educational robots in order to ask essential questions about social and adult perception of software education. For this purpose, we proposed the following research questions: 1. What is the frequency of STEAM according to age? 2. What are the frequency of the sub-content of STEAM according to age? 3. Are there any differences in frequency of sub-content in STEAM depending on age?

2.Experiments

This study was conducted on 29 children age 3, 4 and 5 (16 boys and 13 girls) who are attending daycare center located in Seoul, Korea. The research method is determined to analyze children's questions asked during their voluntary play, and all children in the daycare center were confirmed to have no experience with educational robot 'Turtle'. The educational robot 'Turtle' used in this study is turtle-shaped and has various features, such as (programmed motion, sounds, etc.), which is described in Table 1. Since the children under the aged of 18 are minors their parents were asked to submit a consent form to participate in the study, and only those who agreed participated in the study.

Table.1. Introduction to the educational robots 'Turtle' function

	Function	
	1	Card : recognize cards with different colors and show programmed directional movement
	2	Line : move along the black line and move in a programmed direction according to the color of the intersection
	3	Music : recognize 7 colors representing a music note, Do Re Mi Fa Sol La Si, and can make sounds and sing
	4	Graphics : After inserting a pen, draw a programmed shape by recognizing a color card or use it to draw a picture.

This study was conducted in each classroom, which is the most familiar playground for children, reflecting the culture of respecting children's play by voluntary choice. Turtle was presented at a desk in an empty space in the classroom, allowing children to come and explore and play whenever they want during play time, and minimizing teacher intervention during play.

In this study was conducted for five weeks, three times a week for 30 minutes from April 22 to May 18, 2020, with a total of 10,300minutes of play. For this study, data collection was conducted in the form of participatory

observations, using triangular method to record anecdote and two cameras to improve reliability and feasibility, and photos were taken whenever the play situation changed or it was deemed to be an important situation to record. During the study, children experienced line-coding, card-coding and music-coding while they freely explored the turtle robots, and they engaged in various pretend plays such as hospital play, house building play and parking play.

A total of two researcher participated in the participatory observation, and they shared the purpose of the study, the situations to be observed, how to write anecdotes, the role of teachers, and how to take photos and videos with one co-researcher before the study began. The researchers recorded the observation in the form of an anecdote. One of the researchers also wrote a research journal on the same day to collect various data on children's play conditions, and discussed the play content with the children if they were curious about how they played in the previous session. The recordings include 156 photographs, 900 minutes of video with 300 minutes from each camera, and 161 transcription. A total of 243 questions were selected for analysis, with 59 questions by 3-year-olds, 71 by 4-year-olds, and 113 by 5-year-olds. Later, STEAM elements presented in Cho et al. (2013) were categorized into subcategories corresponding to the contents of each elements, and the contents were reviewed along with one childhood education professor to ensure the validity of the categorization and nomination results. Examples of children's voluntary questions about 'turtle' categorized around STEAM elements are shown in Table 2.

Table 2. Examples of voluntary questions for children about 'turtle' categorized around STEAM elements.

contents	Examples of questions
S	• Are you a robot? • Turtles are supposed to be slow, but why are they so fast?
T	• Why are you circling? • Is it okay to have a red light?
E	• How does a turtle eat? • Why is the turtle a robot?
A	• Teacher, where did you buy this? • Do you want to be a friend with me?
M	• (after creating the tunnel) Can a turtle pass through this tree? • (after building a turtle's house with a friend) My house is bigger, right?

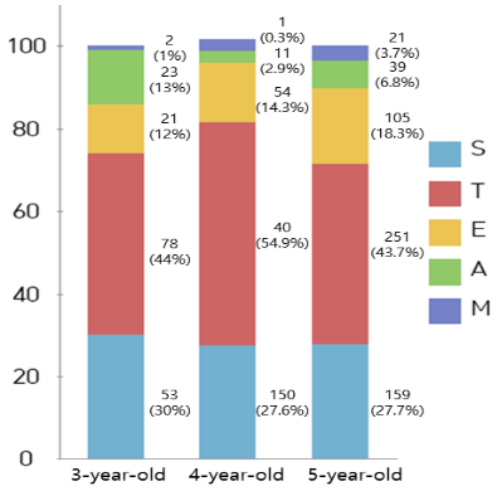
A frequency analysis was conducted to identify the general characteristics of children's questions about turtle categorized around STEAM elements, and a MANOVA was conducted to identify differences in children's voluntary questions about the turtle categorized by age.

3.Results

3.1.Frequency Analysis of Questions Types for Educational Robots in children aged 3, 4 and 5 according to STEAM Elements

The results of the analysis based on STEAM elements by collecting questions about educational robot for children aged 3, 4 and 5 are as shown in Figure 1.

Figure.1 Frequency of questions about educational robots for children aged 3,4 and 5



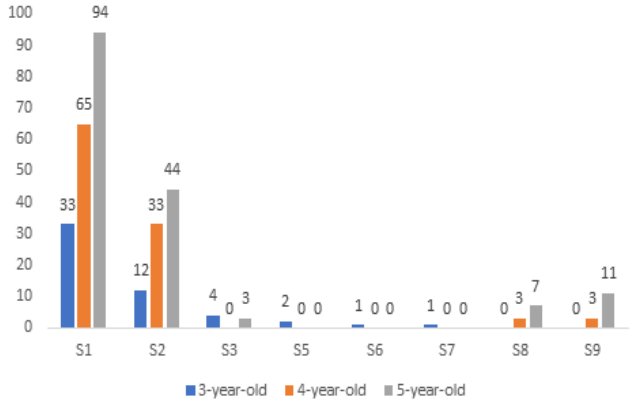
By the STEAM factors, the frequency of questions asked by 3-year-old children were ranked T(Technology) with 44%, S(Science) with 30%, A(Arts) with 13%, E(Engineering) with 12%, and M(Mathematics) with 1%. The frequency results for children aged 4 were T(Technology) with 54,9%, S(Science) with 27.6%, E(Engineering) with 14.3%, A(Arts) with 2.9%, and M(Mathematics) with 3%. The results for children aged 5 were T(Technology) with 43,7%, S(Science) with 27.7%, E(Engineering) with 18.3%, A(Arts) with 6.8%, and M(Mathematics) with 3.7%. The analysis is presented in Figure 1.

The analysis shows that the frequency rank for 3-year-olds in T, S, A, E, and M, and the frequency ranks 4-and 5-year-olds T, S, E, A, and M.

3.2.Frequency Analysis of Question Types for Educational Robots in Children aged 3, 4 and 5 according to Sub-Content of STEAM Elements

The results of the classification of questions classified by STEAM elements into the contents of each element are as follow: The Figure 2 shows the classification of the questions based on the subtext of S(Science) of the STEAM elements. By looking at the results, we can see that S1(the properties of objects and materials) are the highest for all ages.

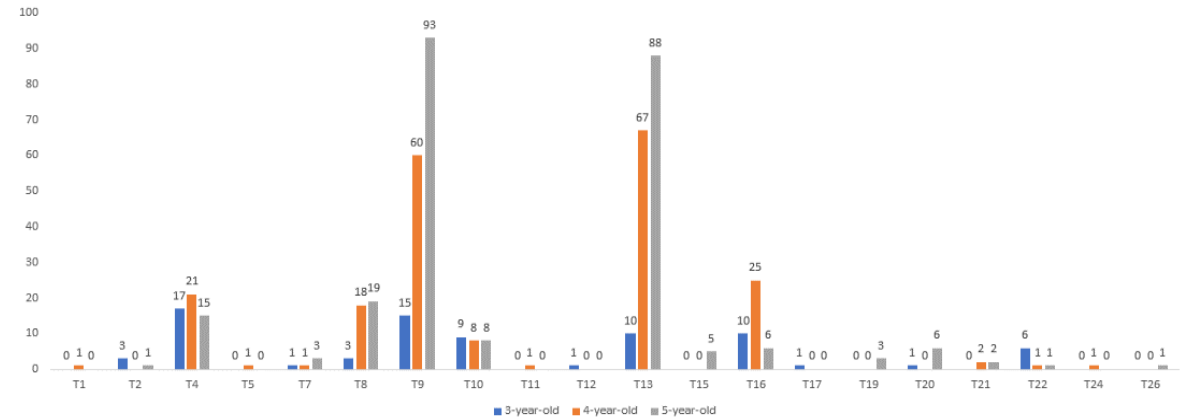
Figure.2 Frequency of questions classified based on sub-content of S(Science)



S1	The properties of object and a substance
S2	The position and motion of an object
S3	Light, heat, electricity and magnetism
S5	A change in the environment
S6	Local problems and science and technology
S7	Science as human endeavor
S8	Technical ability to devise
S9	Understanding science and technology

Figure 3 shows the analysis of the questions by the sub-content of T(Technology). The analysis shows that T9(representing design idea to others, questioning and observing) is the highest for ages 3 and 5, and T13(information collection for daily products) for age 4.

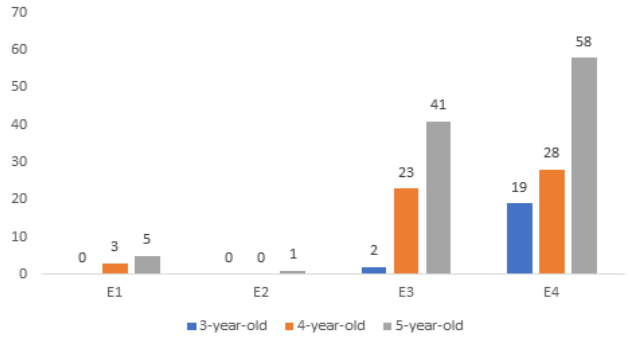
Figure.3 Frequency of questions classified based on sub-content of T(Technology)



T1	People and technology	T13	information collection for daily products
T2	resource	T15	Various forms of energy
T4	Link to technology and other subjects	T16	Individual needs and demands
T5	Benefits and harm	T17	The way people live and work
T7	A creative process	T19	Design to solve problems
T8	Engineering design process	T20	create
T9	representing design idea to others, questioning and observing	T21	Investigate how it is created
T10	All production maintenance is mandatory	T24	Information
T12	Correct and safe use of tools	T26	Product design

Figure 4 presents the analysis of the questions based on subtext of E(Engineering), and it shows that all ages 3, 4 and 5 have the highest frequency in E4(communication and cooperation as engineers).

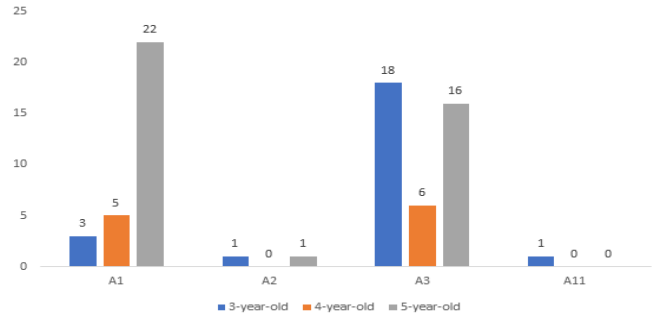
Figure.4 Frequency of questions classified based on sub-content of E(Engineering)



E1	An understanding of engineering design
E2	Connecting and applying engineering to science, technology, and mathematics
E3	Understanding the nature of engineering
E4	Communication and cooperation as engineers

Figure 5 shows the analysis of the questions based on subtext of A(Arts) of the STEAM elements, and it shows that frequency of A3 (Society) was highest at the age of 3 and 4, and A1 (Art) was the highest at the age of 5. It can also be seen that there were questions on A11 (economy) at the age of three, but there were no questions about those by the ages of 4 or 5.

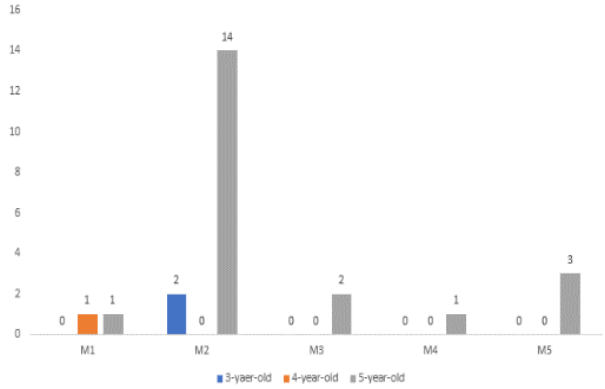
Figure.5 Frequency of questions classified based on sub-content of A(Arts)



A1	Arts
A2	Music
A3	Society
A11	Economy

Figure 6 presents the analysis of the questions based on subtext of M(Mathematics) of the STEAM elements. The result shows that 3-year-olds showed the highest frequency in M2 (space and geometry), but there were no questions relevant to others. One questions appeared in M1(number and computation) for the 4-year-olds and the question appeared in various sub-content for the 5-year-olds, and we can see that M2(space and geometry) has the highest frequency.

Figure.6 Frequency of questions classified based on sub-content of M(Mathematics)



M1	Number and oepration
M2	Space and geometry
M3	Measurement
M4	Patterns and algebra
M5	Organization and analysis of data

3.3.Analysis of the differences in the types of questions about educational robots for children aged 3, 4 and 5 according to the content of STEAM by age

The analysis of the differences in the types of questions about educational robot for children aged 3, 4 and 5 according to the STEAM element is shown in Table 3 below.

Table.3. Analysis of Questions Difference of Children aged 3, 4 and 5 according to the content of STEAM by Age

Independent variable	Dependent variable	Lamda of Wilks	F	Degree of freedom	Significance probability	η^2	Independent variable	Dependent variable	Lamda of Wilks	F	Degree of freedom	Significance probability	η^2
Ages	S1	.08 (p=.000)	1.92	2/194	.149	.20	Ages	T17	.08 (p=.000)	2.48	2/194	0.87	.03
	S2		.77	2/194	.466	.00		T19		1.62	2/194	.200	.02
	S3		4.88	2/194	.009	.05		T20		2.33	2/194	.100	.02
	S5		5.11	2/194	.007	.05		T21		.07	2/194	.930	.00
	S6		2.48	2/194	.087	.03		T22		10.91	2/194	.000	.10
	S7		2.48	2/194	.087	.03		T24		.95	2/194	.390	.01
	S8		1.43	2/194	.241	.01		T26		.53	2/194	.59	.00
	S9		3.12	2/194	.046	.03		E1		.89	2/194	.42	.00
	T1		.95	2/194	.390	.01		E2		.53	2/194	.59	.00
	T2		5.16	2/194	.007	.05		E3		8.21	2/194	.000	.08

	T4	8.81	2/194	.000	.84	E4	3.28	2/194	.040	.03
	T5	.95	2/194	.390	.01	A1	4.56	2/194	.012	.05
	T7	1.07	2/194	.344	.01	A2	.99	2/194	.373	.01
	T8	2.16	2/194	.118	.02	A3	17.14	2/194	.000	.15
	T9	43.77	2/194	.000	.31	A11	2.48	2/194	.087	.03
	T10	3.97	2/194	.02	.04	M1	.24	2/194	.79	.02
	T11	.95	2/194	.39	.01	M2	6.14	2/194	.003	.06
	T12	2.48	2/194	.09	.02	M3	1.07	2/194	.345	.01
	T13	91.64	2/194	.000	.49	M4	.53	2/194	.590	.01
	T15	2.77	2/194	.07	.03	M5	1.62	2/194	.200	.02
	T16	13.78	2/194	.000	.13					

An analysis of age differences in questions about educational robots for children aged 3, 4 and 5 based on the sub-content of STEAM shows that the probability of significance of Wilks is .08, and significance is .000, depending on the age of the children, and the questions vary depending on the STEAM element. Analysis of the differences in questions according to the sub-content of STEAM elements by age showed significant differences in S3, S5, S9, T2, T4, T10, T13, T16, E3, E4, A1, A3 and M2 for each dependent variable.

4.Discussion

In this study, we wanted to raise questions about adults' perception of unplugged play by exploring questions that arise when children play with educational robots in free play. Based on the results of this study, we would like to discuss what we learned by analyzing the questions asked by the children, and how to apply them at educational sites.

First, 3-year-olds asked questions on T, S, A, E, and M in the order of frequency, and although the frequency was different from those of 4 and 5-year olds, they were all in the same order. Therefore, a similar pattern can be seen at all ages. This suggests that infants may differ in their curiosity and content depending on what environment adults support, indicating that children's play of exploring movable robots encourages innate curiosity and serves as a trigger for communication among friends. Therefore, children have a right to receive support for various play environments, and the 2019 revised Nuri Program (2019) recognizes them as "competent player," so it is necessary to apply these diversity in the play environments to the site and reveal its values. It is significant that the value of educational robots as a play environment and toys for children were discovered in the free exploration. This can be seen as a result of asking questions about teachers' open material and environmental support in the role of teachers being discussed in the national-level curriculum. Kindergarten is the first school that already practices integrated education, and it is meaningful that this research has showed the possibility of integration of moving toys and convergence in child education, and is consistent with the ideas from "Kindergarten is the first school" (Ministry of Education, 2009).

Second, analyzing the questions from this research show that S1 (the properties of objects and materials) for all ages was the highest in the sub-content of the S(Science). S1(the properties of objects and materials) can identify the desire to understand the properties of the first educational robot 'Turtle' and the desire to explore is related to the interest of the children. The interest is a factor that leads to learning, so it can be seen that there is an interest in educational robots among young children. Considering the exploration process from a constructivist perspective in which play can be enjoyed and learned in their own way, the result of this study reveals the value of educational robots. This study also confirms that reasoning and thinking of children in the exploration process of educational robots plays a major role (gawk, 2004), while revealing their 'affinity' to educational robots by capturing voluntary questions in their own way without adult intervention.

The sub-contents of the T(Technology) element showed different frequencies for all ages 3, 4 and 5. At age 3, T4 (the link between technology and other subjects) was the highest. This shows that children acquire knowledge about a turtle as an animal by comparing them with the educational robot. The process of finding commonalities and differences while comparing real turtles and educational robots is in the common thread as assimilation and accommodation emphasized by Piaget cognitive development, which reveals that children have experienced "leadership in finding answers to cognitive conflicts" through their previous experience and connections in new

situations. In addition, T13 (information collection for daily products) was the highest at the age of 4, which can express curiosity about an object in words and confirm the children's intention to communicate with people around him/her. In particular, early childhood has had a positive impact on T(Technology) thinking through the process of verbal expression of curiosity about educational robots, as well as learning social values and attitudes through communication with others. And T9(representing design idea to others, questioning and observing) was the highest at age 5, indicating that children aged 5 are better at expressing their thoughts in words than those aged 3 or 4, so they not only communicate their curiosity but also actively week to satisfy their curiosity. An active attitude toward exploring educational robots suggests that it has a positive impact on various educational activities using educational robots in the future, and reveals that educational robots have a great impact in children's personal expressions, communication with members, and sharing idea. Furthermore, these results suggest that adults need to expand their view of educational robots or moving playgrounds as concrete objects, such as play media and play environment, not just as simple machines and tools.

The sub-content of the E(Engineering) element showed the same frequency rank for all ages, and E4(communication and cooperation as engineers) was the highest.

The sub-content of the A(Arts) element shows that 3-year-olds have question frequency in the order of A3(social), A1(art), A2(music), A11(economy). A3(social) type questions include "Turtle, will you be friends with me?" and "Is this Turtle a man? A woman?" and A11(economy) "Where did you buy this?". The frequency order of 4-year-olds' questions is A3(society) and A1(art). Examples of A3 (society) type questions are "Teacher, how about making a turtle bed?" and A1(art) "Why is yellow here?". The order of the questions by children at the age of 5 shows A1(art), A3(society), A2(music). A1(art) type questions include "There's light here?", A3(society) "Shouldn't we build our house?" and A2(music) "How long are you singing?". As shown, diverse questions by different age groups shows that children explore educational robots from various perspectives.

The analysis of the sub-content of the M(Mathematics) elements showed that there were much less questions in all ages than other STEAM elements.

Based on the discussion of these finding, the following can be concluded: First, children' questions about educational robots can be seen as an evidence of their interest and curiosity in educational robots. Therefore, we suggest the need to research and develop educational programs based on the questions on educational robots asked by children. Second, it is necessary to improve current and prospective teachers' perception on educational robots. Adults' reluctance on educational robots can make all the educational space less diverse and discourage growth. The future work should include study on teacher education, and development and resulting effects of workshop programs for teachers. Educational should always be set in the direction of children who are 'the owner of the future'. We hope this study contributes to creating a better education environment.

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