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Dimensions of robotic education quality: teachers' perspectives as teaching assistants in Thai elementary schools

Suparoek Chootongchai [1] **· Noawanit Songkram** [1,2] **· Krerk Piromsopa** [3]

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Abstract
Educational robots have been used in many countries as teaching assistants in elementary schools but robotic education quality is not well established in Thailand. The primary objective of this study was to identify and confirm quality dimensions in robotic education from the teachers' perspectives. The sample size was 510 teachers who were observed in Thai elementary schools. Confirmatory Factor Analysis (CFA) indicated a good fit of a six-factor model to the observed data. The construct of CFA revealed six dimensions of robotic education quality as *Social interaction, Cognitive function, Teaching method, Learner characteristics, Main features and Content*. Results were similar to previous studies. Prototype development of an educational robot was proposed in relation to the Thai educational context. Further research, including large random comparative studies, needs to be performed.

Keywords Social interaction · Cognitive function · Teaching method · Learner characteristics · Main features · Content · Confirmatory factor analysis (CFA)

✉ Noawanit Songkram
noawanit_s@hotmail.com

Suparoek Chootongchai
Suparoek.C@chula.ac.th

Krerk Piromsopa
krerk.p@chula.ac.th

[1] Department of Educational Technology and Communications, Faculty of Education, Chulalongkorn University, Bangkok, Thailand

[2] Educational Invention and Innovation Research Unit, Chulalongkorn University, Bangkok, Thailand

[3] Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand

1 Introduction

Education technology developed rapidly in the twenty-first century and is now gaining popularity as a method to enhance the skillsets of students through innovative teaching tools (Toh et al. 2016). Beran et al. (2011) suggested that many children liked to play computer games or use smartphones during their free time. Children are familiar with technology and capable of completing technical tasks using computers. Consequently, past research indicated promising results of using education technology as learning outcomes for cognitive structures, interests and motivation (Bekele and Menchaca 2008; Benbunan-Fich and Hiltz 2003; Stafford 2005). Studies were also conducted to investigate the use of robots in education as teaching assistants for language, science and technology development (Church et al. 2010; Hirst et al. 2003; Mubin et al. 2012). Results suggested that educational robotics improved the quality of cognitive scores and social skills, indicating that robots can encourage children to become more engaged in their learning activities (Burleson et al. 2018; Deublein et al. 2018; Lu et al. 2018; Ramachandran et al. 2018).

Interest in the use of robotics as teaching aids has increased in recent years. Robots are expected to become an increasingly common sight in classrooms around the world, fueled by a growing demand for technological advancements in the field of robotics. The global educational robot market is predicted to grow from US$778.6 million in 2018 to US$1680 million by 2023 (Wood 2018). Robots are teaching tools that increase the interest of students in the learning process. The future of robots in education is guaranteed and merely requires augmentation and assistance (Hooijdonk 2018) (Fig. 1).

Robotics has many benefits in teaching and learning processes Johnson 2003). This has increased the attention of researchers to develop educational theories such as the theory of constructionism defined by Papert (1993). Constructionism is related to experiential learning in classrooms, and robotics activities can engage children to learn and construct objects more effectively. Sullivan (2008) also emphasized that children can enhance cognitive and learning skills by incorporating robotics in the

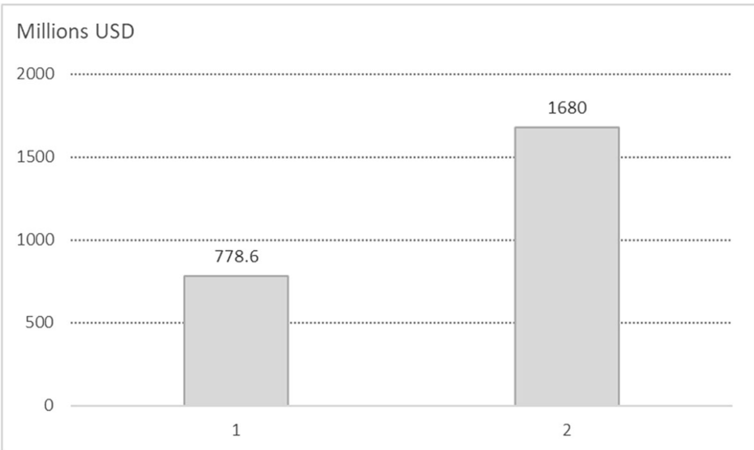

Fig. 1 Educational robots: global forecast to year 2023

teaching of science subjects. Although robotic education has been studied around the world, no research has as yet been conducted in Thailand. This study fills the gap and was designed to identify quality dimensions as perceived by teachers in Thai elementary schools, and confirm the structural features of these quality dimensions by Confirmatory Factor Analysis (CFA) to reveal design factors for robots as elementary school teaching assistants in Thailand. Results can be applied in the context of developing countries.

2 Aims of the study

This study aimed to identify and confirm the quality dimensions of robotic education as perceived by elementary school teachers in Thailand. Results will provide empirical evidence of teachers' perspectives on robotic education quality. This knowledge can be used to improve design factors for robots as elementary school teaching assistants.

3 Literature review

Robotic education was developed (Benitti 2012; Johnson et al. 2016) to integrate teaching methods with new technologies as an instructional strategy using robots as teaching assistants (Ospennikova et al. 2015). The practice of robotics education has resulted in improvement in thinking and problem-solving skills (Kazimoglu et al. 2012), while also increasing student's motivation and attention (Martínez Ortiz 2015; Prensky 2010). However, quality dimensions of robotic education in Thailand are not recorded in the literature, and empirical evidence of teachers' perspectives in elementary schools is lacking. Many studies have extolled the advantages of robotic education but very few have explored facets of structural equation modeling of quality factors to maximize the design of educational service robots as teaching assistants in elementary schools.

Here, robotic education quality was carried out to analyze the use of robots by students at elementary schools. Selected articles focused on systematic reviews and synthesized the findings over the past fifteen years to assess the influence of robots on children in the learning context. Six major factors were examined as (1) Social interaction, (2) Cognitive function, (3) Teaching method, (4) Learner characteristics, (5) Main features and (6) Content. To provide a good starting point, the author also conducted focus group interviews to consider and confirm the important points of each factor (see Table 1).

3.1 Social interaction

Social interaction involves human relations between individuals or groups by forming mutual idea or actions. Children's education must be integrated with their social and emotional development (Fong et al. 2003) by learning as a community (Wolfe 2000). There is wide acceptance that robots can assist students to communicate and interact with others (Fridin 2014). Students can engage in learning different subjects through social interaction with robots (Fong et al. 2003; Keren and Fridin 2014; Kory and

Table 1 Relevant factors of robotic education quality

Proposed factors of robotic education				Researchers						
Dimensions	Item	Sub-dimensions	Description	Jung and Won (2018)	Kubilinskiene, et al. (2017)	Spolaôr and Benitti (2017)	Benitti (2012)	Toh et al. (2016)	Malik, et al. (2016)	van den Heuvel et al. (2016)
1. Social interaction	1	Speech, Facial expression and Movement	Storytelling, Dialogue, Asking questions, Voice and Prosody with set of facial expressions in basic emotions (happiness, sadness, surprise, anger, fear) and body movement with notification	•					•	
	2	Familiarity	Feeling of familiarity, Friend	•						
	3	Stimulus	Flashing lights, Light, Sound, Respond to touch, Play music, Vibrate							
	4	Appearance	Animal-like robots, Cartoon-like robots							
	5	Novelty features	* Perception in artificial intelligence by detection, interpretation and reaction						•	
			* Obstruction avoidance by sensor while moving							
			*People tracking by sensor							
2. Cognitive function			* Linkage to cloud server for data storage							
	6	Pre-test questions	Pre-test question, multiple-choice post-test question, Feedback on thoughts, Simulate testing, User interaction through text input, Choice and control button, Interact for input/output by dynamic screen, Illuminated keyboard, Enabling children to choose robot features that can sustain their interest, Statements to display the correct answer	•						
	7	Post-test questions		•						
	8	Feedback		•						
3. Teaching method	9	Play-based learning	* State of game and sensory rewards (lighting up of the robot's body parts or playing some music or robot's clapping)							•
			* Increase difficulty level of the game to challenge student's ability							
	10	Problem-based learning		•	•	•				

Table 1 (continued)

Proposed factors of robotic education

Dimensions	Item	Sub-dimensions	Description	Researchers: Jung and Won (2018)	Kubilinskiene, et al. (2017)	Spolaôr and Benitti (2017)	Benitti (2012)	Toh et al. (2016)	Malik, et al. (2016)	van den Heuvel et al. (2016)
			Student-centered pedagogy in which students learn about a subject through the experience of solving an open-ended problem found in trigger material							
	11	Project-based learning	Student-centered pedagogy that involves a dynamic classroom approach in which it is believed that students acquire a deeper knowledge through active exploration of real-world challenges and problems	•		•				
4. Learner character-istics	12	Age	Age is a factor that affects the development of knowledge and understanding							
	13	Gender	Gender is a factor that affects the development of knowledge and understanding							
	14	Attention	Attention is a factor that affects the development of knowledge and understanding							
5. Main features	15	Stability	Minimum probability of malfunctioning, Not have fast or jerky movements, Wireless, Long-lasting battery					•	•	
	16	Ease of use	Easy to setup, Easy troubleshooting, Low maintenance, LED to assist child in selection, Touch sensors						•	
	17	Safety	Safe, No risk to children (No sharp edges and accessible electric current), Robust, Modular, Adaptable and Artificial skin					•	•	
6. Content	18	Learning foreign languages	Develop, improve and understand the learning of foreign languages					•		
	19	Learning science	Develop, improve and understand the learning of science							

Table 1 (continued)

Proposed factors of robotic education										
Dimensions	Item	Sub-dimensions	Description	Researchers						
				Jung and Won (2018)	Kubilinskiene, et al. (2017)	Spolaôr and Benitti (2017)	Benitti (2012)	Toh et al. (2016)	Malik, et al. (2016)	van den Heuvel et al. (2016)
								•		
	20	Learning technology	Develop, improve and understand the learning of technology					•		

Proposed factors of robotic education									
Dimensions	Researchers								
	Wong Wai Hong et al. (2017)	Karim, et al. (2015)	Sim and Loo (2015)	Fong et al. (2003)	Leite et al. (2013)	Cabibihan et al. (2013)	Bauer, Wollherr, and Buss (2008)	Focus group interview	Contextual factors
1. Social interaction			•	•	•	•	•	•	•
		•	•	•	•				•
				•	•	•	•	•	•
			•	•	•	•			•
			•	•	•	•		•	•
2. Cognitive function	•			•	•	•		•	•

Table 1 (continued)

Proposed factors of robotic education

Dimensions	Researchers								
	Wong Wai Hong et al. (2017)	Karim, et al. (2015)	Sim and Loo (2015)	Fong et al. (2003)	Leite et al. (2013)	Cabibihan et al. (2013)	Bauer, Wollherr, and Buss (2008)	Focus group interview	Contextual factors
	•			•	•	•		•	•
	•			•	•	•		•	•
3. Teaching method					•	•		•	•
	•							•	•
	•								•
4. Learner characteristics			•						•
			•						•
			•						•
5. Main features						•		•	•
		•	•		•	•		•	•
			•			•	•	•	•
6. Content								•	•
								•	•
								•	•

Selection was influenced by the most frequent factors, while similar statements were considered as important

Breazeal 2014). This has promoted the potential development of students in new actions and cognitive skills (Feil-Seifer and Matarić 2011; Moriguchi et al. 2011).

To build a good emotional relationship, a kind of companionship is developed in response to social needs (Dautenhahn et al. 2006; Friedman et al. 2003; Kazuyoshi et al. 2003a, b, c; Kazuyoshiet al. 2003). People interact more efficiently with development of empathic, intuitive and natural feelings. Chersi (2012), Friedman et al. (2003), Dautenhahn et al. (2006), Fong et al. (2003), Fujita (2001) and Wu and Miller (2005) supported that emotional relationships can also increase acceptability by the society. Therefore, a robot that is supposed to interact with humans should not look threatening but have a friendly appearance and show empathy to understanding and manifesting emotions through its facial expressions, voice, body postures, movements, and gestures to fit the situational context of a conversational partner (Mutlu et al. 2006). Research findings suggested that the robot's empathic behavior positively affected the perception of children (Moriguchi et al. 2011), and most answered that their main motivation was to become "friends" with the robot (Leite et al. 2013).

A social embodied robot must make appropriate use of the social space so that the user can feel safe and comfortable in concordance with his or her personality preferences (Tapus and Mataric 2008). Empathy can have profound positive effects on users' attitudes toward social robots (Brave et al. 2005; Cramer et al. 2010; Hone 2006; Klein et al. 2002; Picard and Liu 2007); therefore, responding to the user's affective experience in a socially appropriate manner is considered a really important issue in achieving user's trust and satisfaction, as well as compliance to requests (Bickmore and Schulman 2007; Brave et al. 2005; Cramer et al. 2010; Dautenhahn et al. 2006; Tamura et al. 2004).

To interact with people, robots must perceive human social behavior and provide conventional functions (respond to touch, localization, navigation, obstacle avoidance) (Fong et al. 2003). Thus, artificial intelligence is used in robots to facilitate human-robot interaction (Cañamero and Fredslund 2001; Ogata and Sugano 2000).

3.2 Cognitive function

Cognitive function involves brain-based skill that extends to acquisition of knowledge and learning new information. Factors of robotics curricula were investigated and children's performances were found to be different depending on: (1) kinds of feedback (feedback from subjects that children recognized), and (2) how children interpreted the feedback and applied it to their tasks (Jung and Won 2018). In the design of robot-student interaction to obtain meaningful learning experiences, the robot can make a dynamic assessment, first through pre-test questions and then by using post-test questions (Haywood and Lidz 2006). Severinson-Eklundh et al. (2003) discussed how explicit feedback is needed for users to interact with service robots. Their approach is useful to provide design features of an interactive robot.

3.3 Teaching method

The teaching method involves the approach for teaching techniques used in the classroom to enable students to achieve their objectives. It is necessary to identify which teaching methods can be considered and integrated with robotics (Altin and

Pedaste 2013). The use of robotics as an educational tool for teaching can shape children's learning on constructivism (Piaget 1973) and constructionism (Papert 1980). The use of robotics should be emphasized in STEM education (Cacco and Moro 2014; Chambers et al. 2008; Datteri et al. 2013; Highfield 2010; McDonald and Howell 2012; Wei and Hung 2011). McLurkin et al. (2013) evaluated the impact of using robots in STEM education. Their results confirmed that a small advanced personal robot is powerful, cheap and robust. A review of teaching methods, applied by using robots by Altin and Pedaste (2013), showed that the most popular methods are problem-based, constructivist and competition-based learning. Besides these main methods, others are discovery learning, communication-based learning, and project-based learning. Nag et al. (2013) and Mathers et al. (2012) supported that problem-based learning can significantly improve student's mathematics, physics, strategic planning, and communication skills, while Altin and Pedaste (2013) argued that educational robotics in STEM subjects lacks evidence that it achieves educational goals in discovery learning, collaborative learning, problem-solving, project-based learning, competition-based learning, and compulsory learning Because of this discrepancy, further research is needed to examine specific teaching methods and pedagogical aspects that need to be considered when adopting robotics (Alimisis 2012). Teacher training must also be taken into account when using educational robots in class (Benitti 2012).

3.4 Learner characteristics

Learner characteristics include age and gender as well as personal characteristics such as interest in learning. The UTAUT (Unified Theory of Acceptance and Use of Technology) model has been used in acceptance of robots (De Ruyter et al. 2005; Heerink 2010; Looije et al. 2006), and states the influences of (i) performance expectancy, (ii) effort expectancy, and (iii) social influence as direct determinants of intention to use (De Ruyter et al. 2005; Heerink 2010; Looije et al. 2006; Venkatesh et al. 2003), with age, gender and interest as significantly moderating factors to behavioral intention.

3.5 Main features

Main features are stability in functioning, ease of use and no risk to children. Many terms have been used to describe robotic acceptance (Heerink 2010; Kidd et al. 2006; Taggart et al. 2005). Most focus robotic features as being easy on the eye and "easy to use" by people who are unfamiliar with robots (Leite et al. 2013). The robots must meet safety requirements and have maximal probability of functioning (Cabibihan et al. 2013). In addition to features, the robot must be robust to allow rough play with children.

3.6 Content

Content as academic input must be provided to the students. The main emphasis centers on the teacher's notion of what academic content is most appropriate to construct the whole course. With the rapid development of technology, robots are being used more in schools (Toh et al. 2016) and children have become familiar with technologically advanced devices (Beran et al. 2011). Studies reported increasing robotic influences on children's cognition, language, interaction, and social and moral development (Kahn Jr et al. 2012; Kozima and Nakagawa 2007; Shimada et al. 2012; Wei and Hung 2011). Interactive learning encourages children to become more engaged in educational activities (Chen et al. 2011; Highfield 2010; Wei and Hung 2011). Mubin et al. (2013) and Benitti (2012) found that robots are now increasingly being used in learning language, science and technology. Studies conducted by Chang et al. (2010), Young et al. (2010) and Hong et al. (2011) determined that robots are being used to teach a second language in primary schools. Results showed that robots could create interactive and engaging learning experiences; the children responded with high motivation and this also enabled students to concentrate better in their learning of linguistics (Chen et al. 2011) and story expression (Sugimoto 2011). A study conducted by Barker and Ansorge (2007) examined students' achievement scores with the use of robots in their science curriculum, while results from another experimental study conducted by Kazakoff et al. (2013) supported the use of programming. Barker and Ansorge (2007), Highfield (2010), Whittier and Robinson (2007) and Barak and Zadok (2009) found that robotics was effective in learning and understanding science, engineering, mathematic and technological concepts.

4 Methodology

4.1 Participants

Participants were selected using multistage sampling of teachers in Bangkok, Thailand. A sample of 510 teachers was selected from large, medium, and small-sized elementary schools in all districts. Teachers in private schools numbered 255 with 255 at public schools. A multistage sampling method was selected as the hierarchical structure from clusters (grades 1 through grade 6). A different grade was randomly sampled from a name list of teachers based on clusters of specific subject areas. Hair et al. (2014) suggested the absence of criteria to determine sample size using Confirmatory Factor Analysis (CFA). One alternative method is the technique of Partial Least Squares (PLS) by Chin et al. (2003). The heuristic requires ten times the construct with the largest number of structural paths. This method indicated 10*27 = 270 as an adequate sample size. In this study using PLS and CFA, the first heuristic was considered. The usable sample size of 510 exceeded the suggested sample size of 270 and was, therefore, determined as adequate by the power calculations.

4.2 Procedure

Mixed methods research by combining qualitative and quantitative approaches was selected (Creswell and Creswell 2017). Qualitative interviews and a quantitative survey were combined to examine factors relating to teachers' perceptions on the quality of robotic education. Four phases are depicted in Fig. 2.

Phase 1: a literature review was conducted to explore contextual factors relating to robotic education by selecting systematic reviews on the use of robots as educational tools.

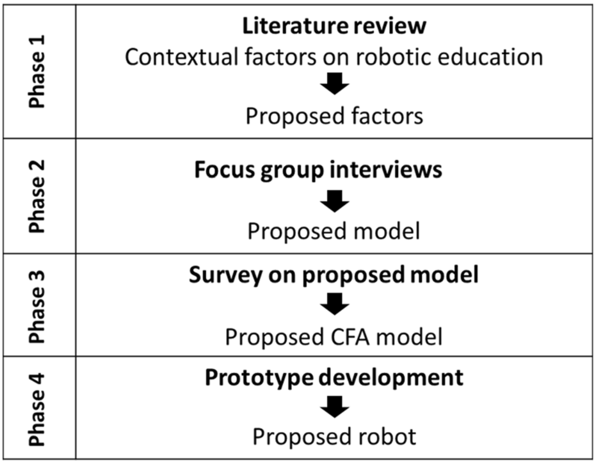

Fig. 2 Research methodology

Phase 2: focus group interviews were conducted with professionals to verify and confirm the contextual factors and create a model. Fifteen interviewees were contacted for open-end recorded interviews, with each lasting about three hours. Three groups of five professionals comprised a technology group, learning and teaching group and robotic group.

Phase 3: a survey questionnaire was created containing 29 questions divided into two sections. Section A collected respondent's demographic information and background (8 questions), while section B contained 21 questions concerning the perceived importance level of contextual factors. The questionnaire was rated on a five-point Likert scale from 1-lowest importance to 5-highest importance for factors of (1) Social interaction, (2) Cognitive function, (3) Teaching method, (4) Learner characteristics, (5) Main features, and (6) Content. Confirmatory Factor Analysis was carried out using LISREL to examine the structure of the contextual factors (CFA model).

Phase 4: this phase developed a prototype for robots as elementary school teaching assistants. Appearance, functionalities, service, and learning processes of the robots were considered in the design.

5 Results

5.1 Confirmatory factor analysis

Confirmatory Factor Analysis (CFA) following the maximum-likelihood estimation method was conducted using LISREL (linear structural relations) to confirm the factor structure. Good model fit was evaluated by the Chi-square statistic which compared the tested model and the independent model with the saturated model (χ^2 /df), Comparative Fit Indexes (CFI), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index

(AGFI), Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). According to Jöreskog and Sörbom (1996), χ^2 /df value less than 2.00, CFI and GFI values more than 0.95, AFGI value more than 0.90, and RMSEA and SRMR values less than 0.05 indicate a good-fitting model. Results of fit indexes are provided in Table 2. The study model showed acceptable values (χ^2 /df = 1.296, CFI = 1.000, GFI = 0.970, AGFI = 0.950, RMSEA = 0.024, SRMR = 0.021) which indicated good fit to the observed data (*P* value >0.05).

The CFA model with a six-factor structure is shown in Fig. 3. Factor loadings ranged from 0.45 (Main features) to 1.06 (Teaching method). The "Teaching method" dimension was the best indicator of robotic education quality perceived by teachers, with "Content" as the second influential dimension in teachers' perspectives.

At item level, the CFA result disclosed that factor loadings varied from 0.48 (Item13) to 0.83 (Item16). In the Social interaction dimension,"Item2" showed high potential. In the Cognitive function dimension, "Item6" was strongly influential. In the Teaching method dimension, "Item10" was the most powerful, while for Learner characteristics, "Item14" was the most important. In the Main features dimension, "Item16" was the most dominant and finally, in the Content dimension, "Item21" showed high effects compared with the others.

Data confirmed the six-factor model as a good fit to explain the observed data collected from teachers. Among the factors or dimensions, Teaching method was more influential than other dimensions, while Main features showed less ability to explain the teachers' perspectives in robotic education quality. Surprisingly, a direct influence of 0.41 was found between Content and Main features.

5.2 Appearances and functionalities of educational robots

Results indicated that the friendly appearance of an animal-like or cartoon-like robot with a cute design will enhance interest and willingness to interact with students. Robot design should be simple for easy interaction with students (flashing lights, sound, vibration and touch responses) with robustness and stability (minimum probability of malfunctioning), while also being easy and safe to use. Figure 4 presents a robot for student education in Thai elementary schools.

A robot can also maintain student interest if it can present non-repeating responses, autonomous movement and facial expressions. Robots are different from computers

Table 2 Fit indexes for the model

Fit indexes	Level of acceptable fit	Model	Result
χ^2 /df	< 2.00	1.296	Pass
CFI	> 0.95	1.000	Pass
GFI	> 0.95	0.970	Pass
AGFI	> 0.90	0.950	Pass
RMSEA	< 0.05	0.024	Pass
SRMR	< 0.05	0.021	Pass

Results of CFA confirmed that the six-factor model was appropriate to explain teachers' perspectives on robotic education quality

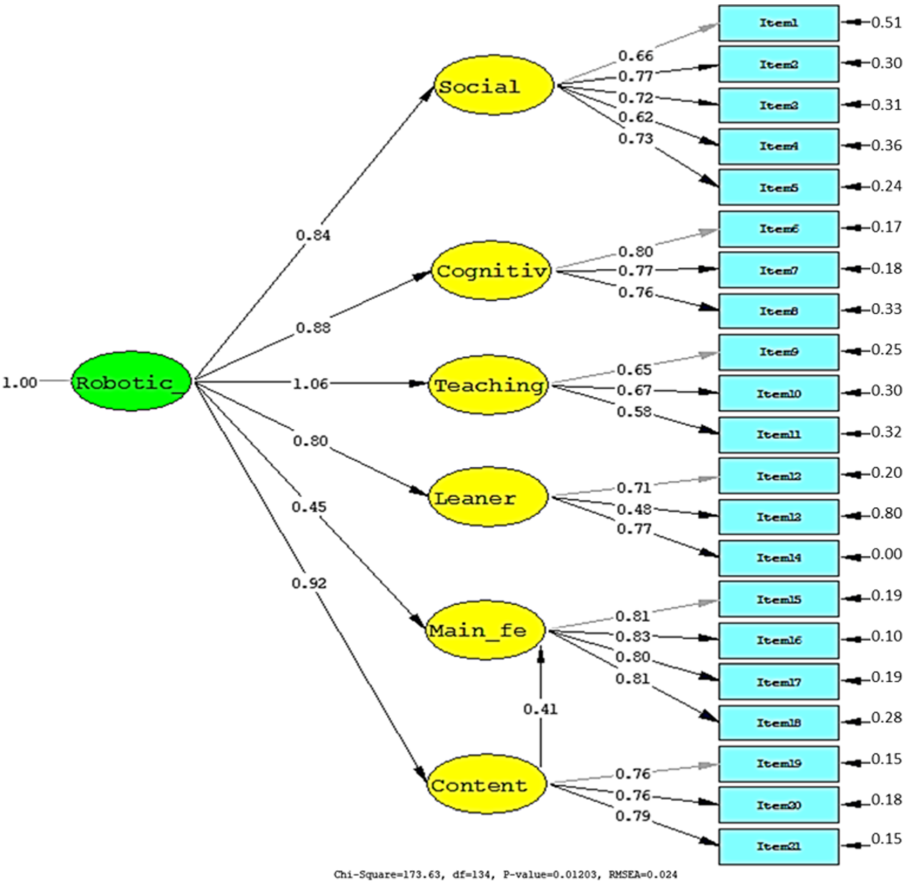

Fig. 3 CFA model showing how the six dimensions explain teachers' perspectives on robotic education quality

and mobile devices in that they have interactive relationships (feelings of familiarity through emotive expressions of happiness, sadness, surprise, anger, disgust and fear). They are capable of social relations (smiling, greeting, walking, inviting to play games or telling stories). Moreover, robots have perceptions in artificial intelligence by detection, interpretation and reaction similar to computers or mobile devices.

5.3 Services of educational robots

To develop, improve and understand the learning of technology, science and foreign languages, robots can provide educational services by visual learning content in body screen displays. The service has context-based actions. Students can interact with the learning content and pre/post-tests through text input, choice and control buttons on a dynamic screen. Statements will display the correct answer (Fig. 5).

An educational robot can increase learning interest by enabling students to choose robot modes. The following robot modes can be performed: (1) storytelling (the robot

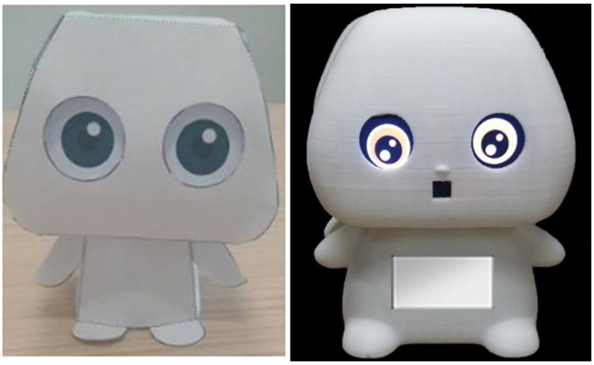

Fig. 4 Robot acceptable by teachers in Thai elementary schools

can tell stories in male or female voices that are ideal for roleplaying), (2) oral reading (the robot can lead students to recite sentences and words), (3) cheerleader (the robot can help the teacher to encourage students to take part in games) (4) command mode (the robot can command students to perform specific tasks), and (5) question and answer (the robot can comment and communicate its feelings and emotions).

5.4 Learning process of students and teachers with educational robots

The learning process with an educational robot is problem-based as a student-centered pedagogy, whereby students learn about a subject through the experience of solving an open-ended problem found in trigger material. This process includes five states: imagining, creating, playing, sharing and reflecting. Moreover, the instructional process is gamified by a play-based learning scenario (state of game and sensory rewards).

Firstly, the teacher explains the activity process by introducing the scenario to the students. At the beginning, in the imagining state, the students read the story and imagine what the solution could be by pre-testing the robot. In the creating state, the students study learning resources guided by the robot and create solutions. Next, in the playing state, students play the game together and increase difficulty levels to challenge their ability. During the sharing state, students and teacher share their experiences, feelings and ideas. Finally, in the reflecting state, the students identify problems and attempt to redesign solutions. All students need to complete the post-test. Implementation of the instructional process is represented in Fig. 6. To promote education quality

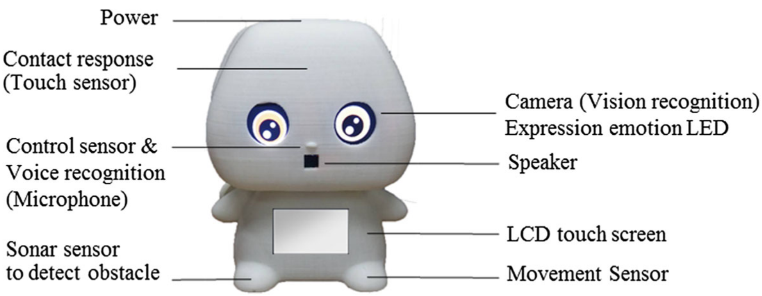

Fig. 5 Overview of hardware structure

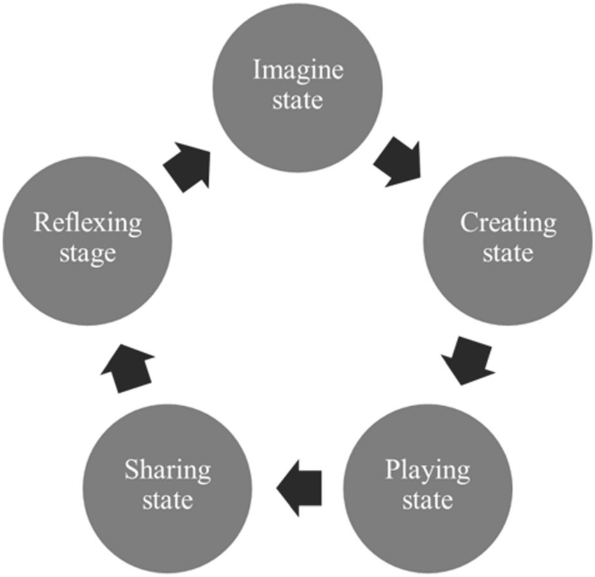

Fig. 6 Learning process with an educational robot

in schools successfully, student characteristics are also an important factor. Results indicated that age, gender, and attention had the highest influence on the development of knowledge and understanding.

6 Discussion

Currently, educational environments with technological support have been integrated in classrooms. Robotic education will inevitably become the main learning and teaching process. Robots can be used as teaching assistants to accompany and encourage student participation through interaction and engagement (Gómez 2018). The findings of this research can be adopted and practiced in Thai elementary schools to increase education quality. This study confirmed that all proposed dimensions of robotic education quality perceived by teachers are important to students.

Social interaction appeared to be influential in robotic education quality. This finding supported previous studies conducted in other countries (Breazeal et al. 2016; Fong et al. 2003; Westlund et al. 2017a, 2017b). Familiarity and novelty features also indicated a strong relationship with social dimension in teachers' perspectives.

Cognitive function was a meaningful dimension in evaluating the quality of robotic education (Jung and Won 2018, and Haywood and Lidz 2006). In the view of teachers, clear pre-test and post-test questions are meaningful indicators of high-quality robotic education. Providers must ensure that accurate, easily-understandable and frequently updated questions are available.

Teaching method was a powerful dimension in determining the quality of robotic education. Pay-based and problem-based learning were seen as powerful indicators in defining robotic education quality. This implies that teachers must provide learning integrated with educational robots to meet students' expectations. Jung and Won (2018) and van den Heuvel, et al. (2016) also empathized this dimension in line with robotics education trends regarding student learning.

Learner characteristics were a significant dimension in assessing the quality of robotic education. This finding concurred with Sim and Loo (2015) who suggested that age and attention are essential factors that impact on the development of knowledge and understanding.

Main features and *Content* were recognized by the teacher when considering the quality of robotic education. All main features must contain stability, be easy to use and safe to be recognized as being of high robotic education quality. This dimension was also influenced by Content (0.41) as seen in Fig. 3, indicating a close relationship. Content was established as a Main feature for increased robotic education quality to enable student learning to be recognized. Toh et al. (2016) and Malik, et al. (2016) provided additional evidence that these six dimensions were perceived by many research articles in the children's context.

7 Conclusions

The purpose of this study was to identify dimensions of robotic education quality and to confirm the structural features of these dimensions. Results of Confirmatory Factor Analysis (CFA) confirmed that the model of six dimensions as (1) Social interaction, (2) Cognitive function, (3) Teaching method, (4) Learner characteristics, (5) Main features and (6) Content presented a good fit to the observed data from teachers' perspectives and revealed that all six dimensions are important in evaluating the quality of robotic education.

Statistics calculated with regard to CFA and model data fit gave Chi-square/degree of freedom: χ^2 /df as 1.296, CFI as 1.000, GFI as 0.970, AGFI as 0.950, RMSEA as 0.024 and SRMR as 0.021. The goodness of fit indexes obtained in relation to the model gave a good fit to the observed structure.

Data were collected from teachers in Thai elementary schools. Prior to the data collection process, a literature review was conducted to explore the contextual factors on robotic education. Expert opinions were received from focus group interviews to verify and confirm the contextual factors before creating the model. The proposed model was presented after receiving feedback and revisions were made.

The CFA result suggested appearance and functionalities as important dimensions of robotic education quality. Services of educational robots were identified together with the behavioral patterns of students and teachers for the learning process.

This research is significant as one of the first studies to investigate the transformation of robotic education into the Thai environment. Results will pave the way to define Thai teachers' perceptions of robotic education quality in elementary schools as important for learning outcomes such as attitudes toward subjects, motivation and academic performance. Future studies may attempt to draw valid comparisons between the Thai context and other countries in the design of valuable educational robots for learning purposes.

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