Research Trends in Lego and Robotic Usage in Education: A Document Analysis[1]

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Abstract

The purpose of this study is to examine Lego and robotics interventions in education. For this aim, 45 master's theses and doctoral dissertations published between 1991 and 2014 with Lego, robotic, and first Lego league keywords were examined. Data were classified according to methods, sample sizes, and variables. Results and suggestions from the manuscripts were also categorized. Document analysis was conducted in order to identify and show general trends. Findings are presented descriptively with charts and tables. The topic was most popular in 2013, and almost half of the studies preferred quantitative methods. Surveys were the most popular data collecting tool, and interviews were second. Sample size changed according to research method, and secondary school students were the most common participants. Surprisingly, most researchers omitted details about data collection time and process. Of those who responded, most dedicated 6 to 8 weeks to data collection. Generally, results showed that incorporating Lego and robotics leads to increased motivation and self-confidence, just like every new technology. Some researchers investigated Lego and robotic usage and perception of gender stereotypes with positive outcomes. Using Lego and robotics also reduced anxiety towards math and science in women. Nearly all researchers suggested longer term studies to gain a clearer vision about this topic. The results of this study will be helpful for guiding future research in this area.
Keywords: Lego, robotic, document analysis

1. Introduction

In the last century most country aimed to raise successful people which good at in science, technology, engineering and math against coming out economic problems. For this aim, countries have developed new reforms in science and math education systems (Ciltas, Güler & Sozbilir, 2012). In United States after Russia launched the first artificial space orbit Sputnik in 1957 the importance of awareness of science and other fields has arisen. So new education reforms like NDEA developed for raising contribution in science and math areas (Laughlin, 2013). In 2001, No Child Left Behind Project has started and all of students had standardized test in all over nations. With respect to this all of students had same opportunity to increase their problem solving, reading and math skills (Guclu & Bayrakcı, 2004). Turkey also has followed these developments with opening first science high school in 1964 and then continued new reforms as years past in science with the scope of constructivist idea (Ciltas & others, 2012)

In the last two decades PISA exam is using as a criterion for understanding the effectiveness for countries education policies and student achievement in higher order skills. The exam aims to test 15 years old students reading skills, problem solving and other higher order thinking skills against real life situations (OECD, 2012). In every three years the exam was taken place and Turkey has attended first in 2003 (OECD, 2012). But despite every attendance and raising scores still the country showed low results among other countries in 2006 and 2009 (Eğitimin çıktıları, 2010). So the curriculum has changed recently with more cognitively and constructivist way (Çelen, Çelik & Seferoğlu, 2011). The new curriculum is aimed to teach not only knowledge and comprehensive level based skills but also other steps of Bloom's taxonomy to the students in science and technology lessons (MEB, 2006). But because of the education programs doesn't flexible and constructivist enough the evaluation of programs showed negative results for educating students with 21st century skills (Arsal, 2012). To overcome this negativity educators must re-shape learning environments for learners. Because of the modern need to enrich problem solving, critical thinking, and computational skills, some educators and researchers have turned to Lego toys and robotics systems. Lego offers students the opportunity to model an idea, gain hands-on experience, and apply alternative thinking while working with peers (Nugent, Barker, Grandgenett & Adamchuk, 2009). Using math and science concepts in real life helps children to learn correctly and gain long-term knowledge from early ages, and this topic has become a growing point of interest in academic research. The purpose of this study is to examine Lego and robotics interventions in education. To accomplish this goal, 45 master's theses and doctoral dissertations were found featuring relevant keywords in Proquest and YOK.

A series of research questions was then established to determine and assess their content and results:

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Research Questions

1) What is the distribution of thesis by years?
2) a) Which research methods were commonly used in thesis?
   b) What is the distribution of research methods by master and doctoral thesis?
3) Which data collection tools were commonly used in thesis?
4) a) What is the common range of sample sizes in thesis?
   b) Which sample levels were commonly used?
   c) Which sample selection methods were commonly preferred?
5) a) What data analysis methods are commonly used in thesis?
   b) What is the distribution of data analysis methods by research methods?
6) What is the most selected time for data collection among thesis?
7) Which variables most preferred in thesis?

2. Method

Document analysis was employed in this study in order to understand current trend of master and doctoral thesis about Lego and robotics. Document analysis is a technique which allows to examine related written and printed papers of certain topic (Yildirim & Simsek, 2005). The documents was selected according to having "Lego" or "robotic" or "First Lego League" keywords in STEM education and searched in YOK and ProQuest databases until April, 2015.

2.1. Data Collection Tool

Each thesis analyzed by using the '*Papers Classification Form* (PCF)'. PCF is first developed by Sozbilir, Kutu & Yasar (2012). Then the form modified by Göktaş and others for Educational Technologies. In this study the modified version was used according to finding answers to our research questions. The original form has seven components which provide descriptive information for the identification of the paper, sub-disciplinary area of the paper, subject (title) of the paper, methods employed in the study, data collection tools used, sampling and sample sizes, data analysis methods, research questions, results and implications of thesis. But in this study paper title was restricted with Lego and robotic. Also two new components were added such as variables and data collection time/process.

2.2. Analysis of Data

Data gathered from the thesis with content analysis were analyzed by using descriptive statistics. Then percentage and the frequency of the items were calculated.

3. Findings

3.1. Distribution of Thesis by Years

Lego and robotics usage in science lessons is very common currently. The first thesis on this topic was published in 1991 in the USA, and while there was a considerable lull from 1991 to 2001, it has been studied almost every year since, with nine theses in 2013. Table 1 below represents the thesis which analyzed in this study.

Table 1

Context of the thesis and major aims

Author*	**Year**	**Type** (M/D)**	**Method**	**Details of Study *****	**Aim of The Study**
Lenamond	1991	M	Quantitative	Quasi experimental, ANOVA, Purposeful sample	To understand the impact of computer-based technology on certain aspects of problem solving.
Pollock	1997	D	Quantitative	Quasi experimental, ANOVA, Easy accesible sample	To investigate differences in students' cognitive abilities and school attitudes between two groups.
Wu	2001	D	Qualitative	Case Study,Content Analysis, Easy accesible sample	To teach STEM concepts with using a Lego Project.

Hacker	2003	M	Qualitative	Case Study,Content Analysis, Purposeful sample	To give real life experience to students with using robotics.
McDaniel	2004	D	Qualitative	Case Study,Content Analysis, Purposeful sample	To discover how deaf students used problem solving skills during sessions with LEGO activities.
Berry	2005	D	Quantitative	Quasi experimental, Descriptive analysis, Random sample	To understand teachers view's on students attitudes and motivations about FLL(First Lego League)
Cameron	2005	M	Qualitative	Case study	To understand how robotics may effect on students learning process by the means of activity theory
Griffith	2005	D	Quantitative	Quasi experimental, Descriptive analysis, Random sample	To understand how FLL effects students motivation in STEM lessons
Varnado	2005	D	Quantitative	Non-Experimental, Correlational, ANOVA, MANOVA, Regression, Easy accesible sample	To understand how FLL effects students problem solving skill development
Vollstedt	2005	M	Mixed	Triangulation, Easy accesible sample	To improve student knowledge and interest in STEM
Ribeiro	2006	M	Qualitative	Case study	To increase student motivation and solve real life problems with robots
Rust	2006	D	Qualitative	Case study	To understand how designing robotic systems can effect coding Java systems.
Gibbon	2007	D	Quantitative	Quasi experimental, Descriptive analysis, Random sample	To improve problem solving skills and 3D skills of students
Welch	2007	D	Mixed	Quasi experimental, Descriptive analysis, Random sample	To understand FLL students opinion's about science and engineering
McWhorter	2008	D	Quantitative	Quasi experimental, ANOVA, ANCOVA, Purposeful sample	To enhance students self regulative learning and motivation
Silva	2008	M	Quantitative	Quasi experimental, ANOVA, ANCOVA, Purposeful sample	To give better instruction in science lesson
Güntürkün	2009	M	Literature review	Document analysis, Purposeful sample	To review historical and structural development of construction toys
Hurner	2009	D	Qualitative	Quasi experimental, ANOVA, ANCOVA, Purposeful sample	To examine the impact of participating robotics competition on high school students' attitudes toward science.
Tse	2009	M	Quantitative	Experimental, Descriptive analysis, Purposeful Sample	To develop an inexpensive, modular, and robust tool.
Çayır	2010	M	Quantitative	Quasi experimental, Non parametric, t test, Purposeful sample	To investigate the effect of Lego on science process skill.
Adams	2010	M	Quantitative	Quasi Experimental, Descriptive analysis, Purposeful Sample	To understand gender differences in students projects

Marulcu	2010	D	Mixed	Interviews, observations, pre-post tests, purposeful sampling	To examine the impact of a LEGO-based, engineering oriented curriculum on simple machines.
Mojica	2010	D	Quantitative	Quasi experimental, t test, Easy accessible Sample	To investigate the robotic effect on critical thinking skill development
Notter	2010	D	Qualitative	Phenomenology, Purposeful Sample	To investigate FLL students motivations and reasons to attend the competition.
Author*	**Year**	**Type** (M/D)**	**Method**	**Details of Study *****	**Aim of The Study**
Jim	2010	M	Mixed	Interviews, surveys, observations	To understand teachers' and students' perceptions about an instruction with Lego
Adams	2011	D	Qualitative	Case Study, Purposeful Sample	To investigate teaching concepts with robotics on disabled students
Coxon	2011	D	Quantitative	Quasi experimental, t test, Random Sample	To increase spatial skills of students
Flannery	2011	M	Mixed	Interviews, surveys, observations	To teach programming in early school years
Howell	2012	D	Mixed	T test and content analyze	To design and develop a robot and improve student attitudes towards robotic concepts
Morris	2012	M	Quantitative	Quasi experimental	To develop cheaper micro mouses with using robotics.
Koç-Şenol	2012	M	Quantitative	Quasi experimental, Descriptive, Purposeful Sample	To investigate students opinions about robotic and the effect of students' scientific process skills and their motivation toward Science and Technology course
Üçgül	2012	D	Qualitative	Case Study, Content Analysis, Purposeful Sample	To explore and design a robotic camp instruction.
Yalçın	2012	M	Quantitative	Quasi experimental, Descriptive, Easy accesssible Sample	To produce a new robotic material in order to provide inexpensive robot.
Koumoullos	2013	D	Quantitative	Non-Experimental, Correlational, ANOVA, MANOVA, Purposeful	To understand the effect of taking a robotic course on academic achievement.
Laughlin	2013	D	Quantitative	Comperative (casual), t test, Purposeful Sample	To compare the relationship between participation in a robotic program and students mathematic scores.
Noble	2013	M	Qualitative	Case Study, Content Analysis, Purposeful Sample	To develop and experience a robotic platform in order to teach science concepts
O'Connell	2013	M	Quantitative	Quasi experimental, Descriptive analysis, Random sample	To produce cheaper robotic prototypes.
Özdoğru	2013	M	Quantitative	Quasi experimental, Descriptive analysis, Random sample	To investigate using Lego Mindstorms on the students' academic achievement, science

					process skills, and attitudes toward the science and technology course
Seddighin	2013	M	Mixed	Observations, Purposeful Sample	To investigate the effects of robotics in early school instruction.
Smith	2013	D	Qualitative	Case Study, Purposeful Sample	To evaluate the underlying motivational attributes or factors that effect participants in robotics project.
Sungur	2013	M	Mixed	Quasi experimental, Descriptive analysis, Purposeful sample	To investigate teachers' and candidate students' perceptions about using robotics in instruction
Webb	2013	D	Mixed	Observations, Purposeful Sample	To explore programming skills and self-efficacy of students
Craig	2014	D	Qualitative	Interviews, Purposeful Sample	To understand if robotics can change gender streotypes in career choice in the field of engineering
Holmquist	2014	D	Qualitative	Quasi experimental, Descriptive analysis, Random sample	To describe the interactive process and outcomes using educational robots understanding of STEM concepts.
Sheneouda	2014	D	Quantitative	Quasi experimental, Descriptive analysis, Purposeful sample	To point out the detrimental effects of gender stereotypes on children's performance in STEM.

* Author: Author's Surname

** M: Master Thesis, D: Doctoral Dissertations

*** That column refers to method, analyses data and sample selection methods of the thesis.

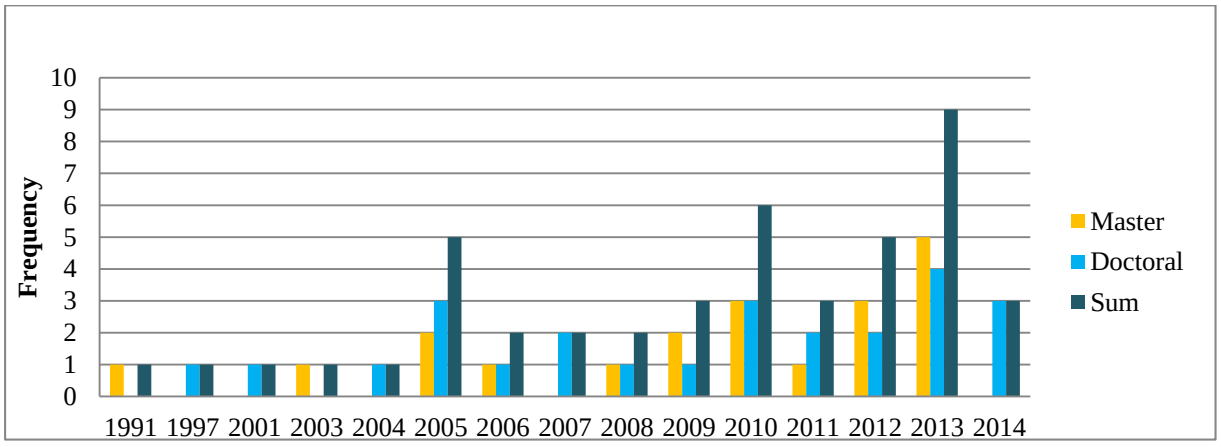

*Figure 1***.** Distribution of thesis by year

3.2.a. Research Methods in Thesis

A significant number of theses studied applied quantitative methods (48.8%). The second most popular method was qualitative (31%), followed by mixed methods (17.7%) and literature reviews (2.2%). Before 2000, no thesis used qualitative or mixed methods. Qualitative methods were popular in 2006, 2009, 2013, and 2014. Mixed methods was first used in 2005 and has become more popular than ever before in the last few years. The only literature review occurred in 2009 in Turkey (see Figure 2).

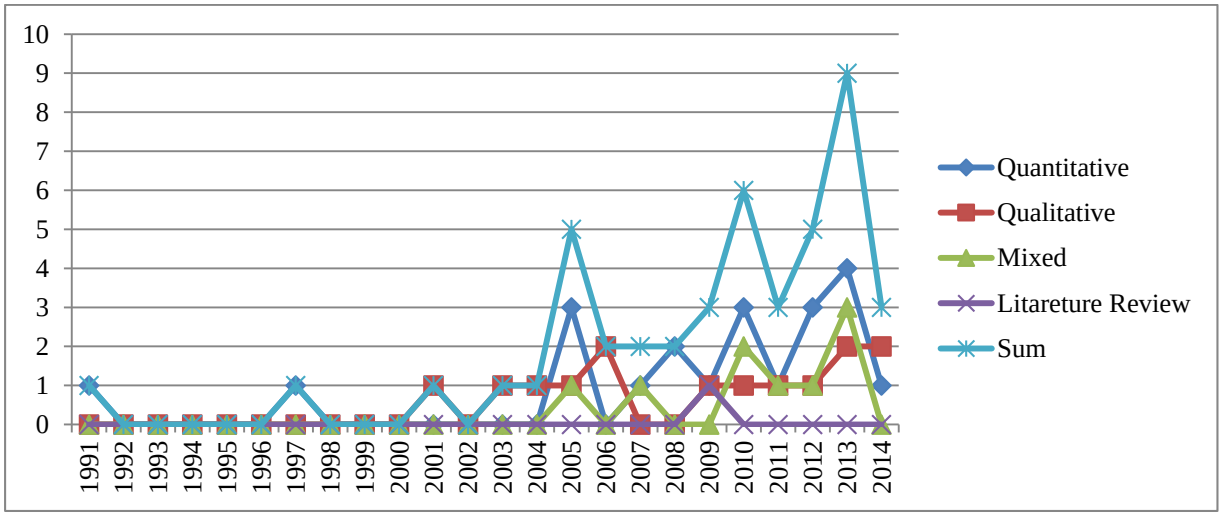

Figure 2. Frequently used research methods in thesis by year

3.2.b. Distribution of Research Methods

Quantitative and qualitative methods were generally used in for doctoral dissertations, while mixed methods were generally preferred for master's theses (See Table 2).

Table 2.

Distribution of research methods by thesis type

Type of Thesis	Research Methods							
	Quantitative		Qualitative		Mixed		Literature Review	
	f	%	f	%	f	%	f	%
Master	10	22,2	4	8,8	5	11,1	1	2,2
Doctoral	12	26,6	10	22,2	3	6,6	-	-
Sum	22	48,8	14	31	8	17,7	1	2,2

3.3. Data Collection Tools in Thesis

As seen in Figure 3, Likert type questionnaires, observations, and interviews were the most preferred data collection tools, followed by attitude and characterization scales. Achievement tests and alternative instruments appeared less frequently, with documents scoring last.

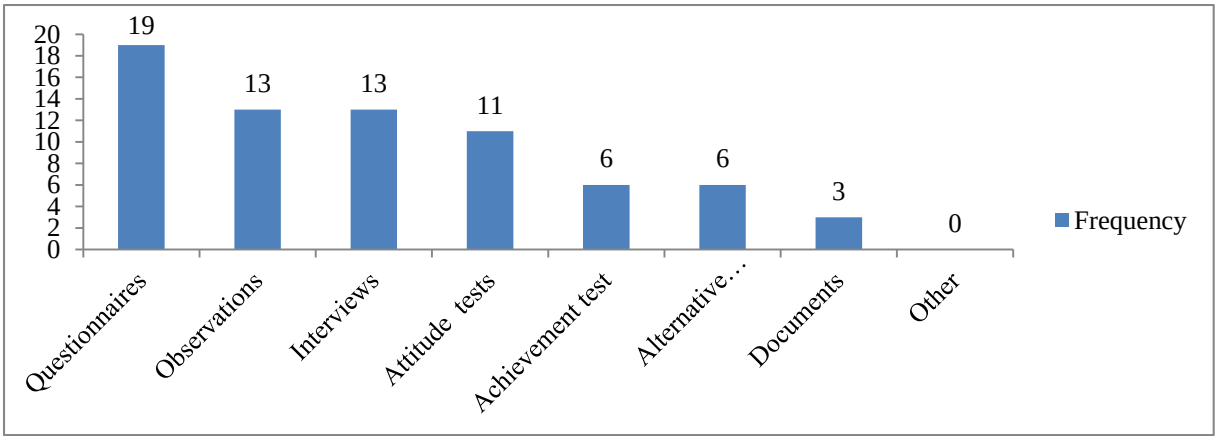

Figure 2. Data collection tools in thesis

When examining data collection tools and research methods together, researchers using quantitative methods most preferred Likert type attitude and characterization scales. For the qualitative method, observations and interviews were mostly used.

Table 3

Data collection tools

Data Collection Tool	Research Method			
	Quantitative	**Qualitative**	**Mixed**	**Literature Review**
Observation	1	10	2	-
Participant	1	10	2	-
Non-participant	-	-	-	-
Interview	1	8	4	-
Structured	-	4	-	-
Semi-structured	1	3	4	-
Unstructured	-	1	-	-
Achievement tests	4	-	2	-
Open ended	-	-	2	-
Multiple	4	-	-	-
Attitude and characterization tests	10	-	1	-
Open ended	-	-	-	-
Multiple choice	3	-	-	-
Likert	7	-	1	-
Questionnaire	10	3	6	-
Open ended	2	-	1	-
Multiple choice	-	-	-	-
Likert	8	3	5	-
Documents	-	2	-	1
Alternative assessment tools	2	2	2	-

Researchers mostly used multiple choice questions in achievement tests, and participant observation for observations. For mixed methods, besides questionnaires and interviews, almost every other kind of data collection tool was used (Table 3).

3.4. Sample Size, Sample Level and Sample Selection Methods

When sample size was examined according to research methods, the smallest quantitative study size was 28, and the largest was 204. In qualitative studies, the smallest size was 3, and the largest was 27. Mixed studies ranged from 48 participants to 312. As shown in Table 3, quantitative studies frequently utilized a 31–100 range, followed by 101–300. Similarly, mixed methods used a 31–100 sample size the most, while qualitative studies used the 1–10 range most.

Table 4
Sample size according to research methods

Sample size	Research Methods		
	Quantitative	**Qualitative**	**Mixed**
1-10	-	7	-
11-30	3	3	-
31-100	11	2	6
101-300	4	-	2
301-1000	1	-	1
Over 1000	-	-	-
Total	**19**	**12**	**9**

Table 5 shows the sample level of participants. The most preferred sample level was clearly secondary school students (n = 21), followed by teachers and high school students. Almost no studies were conducted in preschool or early school.

Table 5

Sample level used frequently in thesis

Sample Level	**F**	**%**
Early school (Preschool)	2	4
Primary (1-4)	5	10,2
Secondary (5-8)	21	42,8
High School	7	14,2
Undergraduate	5	10,2
Post-graduate	-	-
Educators	8	16,3
Parents	-	-
Administrative	1	2,04
Total	**49**	**100**

As shown in Table 6, to understand the effects of Lego and robotics on participants, researchers generally applied purposeful sampling methods, followed by easy and accessible selection.

Table 6

Sample selection method

Sample Selection	**F**	**%**
Purposeful	21	46,6
Easy accessible	16	35,5
Random	7	15,5
Other	1	2,4
Total	**45**	**100**

3.5. Data Analysis Methods

For quantitative studies, inferential statistics were used the most common analysis methods (see Table 7). For inferential methods, regression and non-parametric tests were not as popular as t-tests and ANOVAs. Researchers used descriptive statistics and content analysis when applying qualitative methods, but in mixed and quantitative research, content analysis was most highly preferred.

Table 7

Data analysis methods

Data Analysis Methods	Research Method			
	Quantitative	Qualitative	Mixed	Literature Review
Quantitative Data Analysis	25	-	6	-
Descriptive	7	-	1	-
Frequency/Percentage	4	-	-	-
Mean/Standard Deviation	3	-	1	-
Graph	-	-	-	-
Inferential	18	-	5	-
t-test	4	-	2	-
ANOVA/ANCOVA	7	-	2	-
Correlational	2	-	-	-
Non-parametric	1	-	-	-
Factor Analysis	-	-	-	-
MANOVA/MANCOVA	3	-	-	-
Regression	1	-	1	-
Other	-	-	-	-
Qualitative Data Analysis	-	8	2	-
Descriptive Analysis	-	3	1	1
Content Analysis	-	5	1	-
Other	-	-	-	-

3.6. Data Collection Time

In instances where researchers mentioned data collection time, one year was the longest process duration. While the most popular length was six to eight weeks, studies also often lasted three to five weeks. Surprisingly, most manuscripts (37.7%) did not specify data collection time.

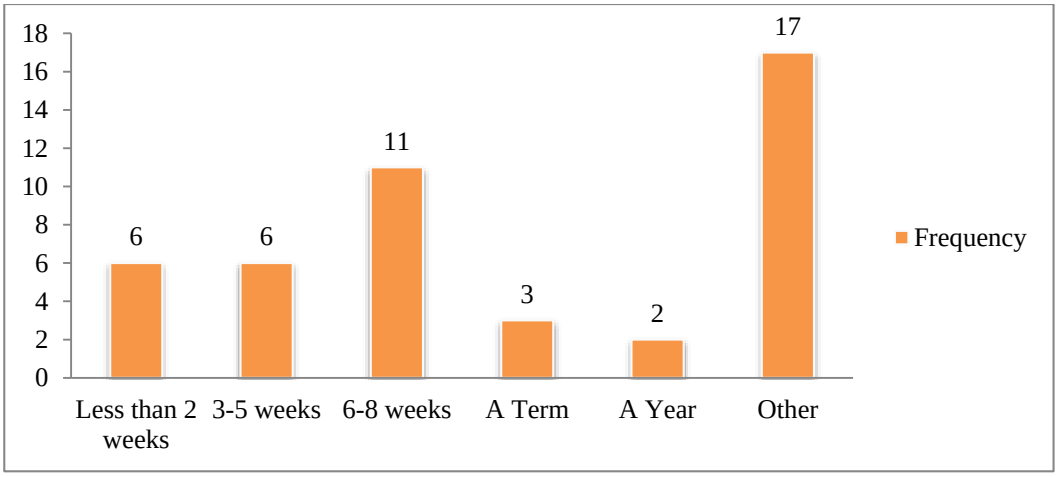

Figure 3. Data collection time

As seen in Table 8, most studies did not mention their data collection times. Five quantitative and five qualitative studies (11.1% each) lasted 6 to 8 weeks.

Table 8

Data collection time by research methods

Data Collection Time	Research Methods							
	Qualitative		Qualitative		Qualitative		Literature Review	
	f	%	f	%	f	%	f	%
Less than 2 weeks	2	4,4	1	2,2	4	8,8	-	-
3-5 week	3	6,6	2	4,4	-	-	-	-
6-8 week	5	11,1	5	11,1	1	2,2	-	-
A term	2	4,4	-	-	1	2,2	-	-
A year	1	2,2	1	2,2	-	-	-	-
Other	9	20	5	11,1	2	4,4	1	2,2
Sum	**22**	**48,8**	**14**	**31,1**	**8**	**17,7**	**1**	**2,2**

The highest response for mixed methods was less than two weeks. The longest period was one year (one quantitative and one qualitative study).

3.7. Most Preferred Variables

As seen in Figure 5, in thesis achievement (academic success) is the most common used variable. This followed with attitude (n=10), problem solving (n=8), motivation (n=4) and gender (n=4).

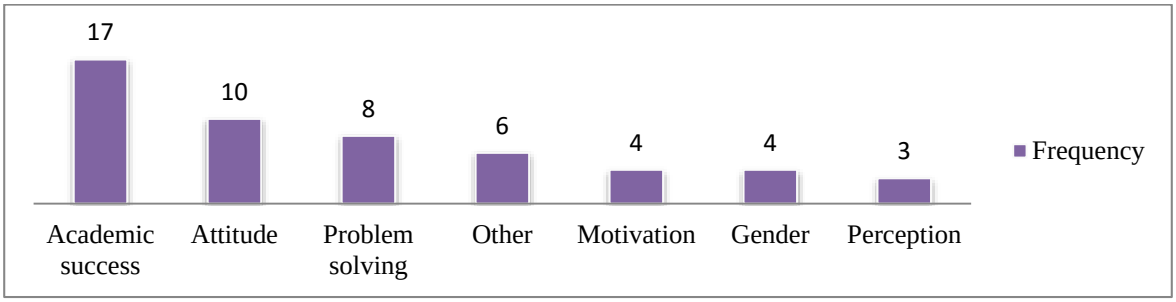

Figure 4. Most preferred variables

According to Table 9 in quantitative studies researchers looking for answers mostly how Lego and robotics effect students' academic achievement or problem solving skills. Also there isn't found any thesis studied with motivation variable in quantitative way. Generally in mixed method studies attitude, problem solving and gender weren't studied as a variable in both master and doctorate thesis. Nevertheless perception still weren't studied with any kind of sample level with qualitative methods.

Table 9

Distribution of variables by research methods

Variables	Research Method							
	Quantitative		Qualitative		Mixed		Literature Review	
	f	%	f	%	f	%	f	%
Achievement	9	16,9	5	9,4	3	5,6	-	-
Attitude	4	7,5	2	3,7	4	7,5	-	-
Problem solving	6	11,3	2	3,7	-	-	-	-
Motivation	-	0	3	5,6	1	1,8	-	-
Gender	2	3,7	2	3,7	-	0	-	-
Other	2	3,7	2	3,7	2	3,7	1	1,8
Perception	2	3,7	-	0	1	1,8	-	-
Sum	**25**	**47,1**	**16**	**30,1**	**11**	**20,7**	**1**	**1,8**

4. Discussion, Conclusion and Suggestions

Lego was once just a toy for many of today's researchers and educators, but as technology has changed, it has become an innovative way to teach science and math concepts. In order to enhance children's engineering and related skills, researchers have been investigating how to develop problem solving, creative, and critical thinking abilities. From 1991 to today, many master's theses and doctoral dissertations have examined using Lego and robotics systems in education.

This study aimed to explore the current situation with Lego and robotics usage when teaching STEM skills. Two databases were searched using three keywords, and 25 doctoral dissertations and 20 master theses were found. Most of the authors studied in America, especially at Tufts University. The studies were classified according to year, methods, data collection tools, sample size and selection, data collection time, and variables. Findings were examined according to study research questions.

The first related manuscript was a master's thesis published in 1991 that investigated Lego usage and problem solving skills in children. The next study was published in 1997. Most of the manuscripts studied were published in 2013 and examined the effects of Lego on motivation, attitude, and academic achievement (Koumoullos, 2013; Laughlin, 2013; Noble, 2013; O'Connell, 2013; Ozdogru, 2013; Seddighin, 2013; Smith, 2013; Sungur, 2013; Webb, 2013). Over time, Lego technology changed, which was reflected in thesis content. Generally, researchers have studied Lego integration in courses when teaching abstract concepts. Developing new school curriculums and after-school courses have also been topics of doctoral dissertations (Marulcu, 2010; Uçgul, 2012). The reason fewer studies have taken place in Turkey than abroad might be because of language barriers and the high price of products. Accordingly, some researchers have aimed to develop new systems instead of using Lego brand products (Morris, 2012).

As for research methods, quantitative methods were prominent (49%), followed by qualitative studies (31%) and mixed methods (18%). Another content analysis conducted on master's theses in computer education and instructional technology found similar results (Akça-Üstündağ, 2013), and the current findings also parallel other literature reviews (Bozkaya, Erdem Aydin & Genc-Kumptepe, 2012; Ciltas et al., 2012; Sumak, Hericko, & Pusnik, 2011). Mixed methods has been used more frequently in the last few years, especially for master's theses (Ciltas et al., 2012; Simsek et al., 2008).

Likert type questionnaires, observations, and interviews were common data collection tools. While Likert type questionnaires were highly used in quantitative studies (45.5%), in qualitative studies, observations (71.42%) were most preferred. In mixed studies, data were more frequently collected by questionnaires (75%) and interviews (50%). In addition, data were usually collected with more than one tool.

In terms of samples and sample sizes, the majority were secondary school students, parallel to the findings of Barreto and Benitti (2012), and the sizes ranged from 31 to 100 in both quantitative and mixed methods. Qualitative method sample sizes generally ranged from 1 to 10. No thesis was studied with more than 1000 participants, and the most common sample selection method was easy and accessible. This result has also been found in other studies (Alper and Gulbahar, 2009; Goktas et al., 2012) Young children, who are at a difficult age for evaluating skills, and parents were rarely selected as study participants.

When data analysis methods were examined, researchers of quantitative studies highly preferred inferential analysis, but in mixed and qualitative studies, researchers mostly used descriptive analysis. The data collection process commonly lasted 6 to 8 weeks for quantitative and qualitative studies, but mixed methods research often lasted less than 2 weeks. Surprisingly, most manuscripts gave no clues about the data collection process, which is a reliability problem. Also long term studies were generally only conducted by doctoral students, who presumably had more time for practice and data collection than master's students.

Regarding variables, researchers mostly examined academic achievement. Quantitative studies investigated both achievement and problem solving skills. Motivation was often studied in qualitative studies, but not in the quantitative studies as well. In mixed studies, attitude was a popular variable, while problem solving and gender were not studied. Gender was a common variable for both qualitative and quantitative methods, especially about female carrier choice, stereotypes, and science and engineering perceptions. Researchers have used this topic to reduce misconceptions and prove female success in those fields (Adams, 2010; Craig, 2014; Hurner, 2009; Sheneouda, 2014). Another category of variables was applied for developing curriculum or organizing science and math lessons with Lego. The research questions, results, and implications of these manuscripts demonstrate that even though there has not been a significant increase in academic achievement, motivation and attitudes about Lego usage have both improved dramatically. These theses and dissertations have also presented significant changes in problem solving, critical thinking, and creativity. However, longer periods of data collection and larger sample sizes improve research, and Lego and robotic systems are expensive, so governments or authorities must support, sponsor, and help fund future studies (O'Connell, 2013; Holmquist, 2014; Koç-Şenol, 2012; Vollstedt, 2005) .

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