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Full Length Research Paper

The effect of pattern-based mathematics education program (PMEP) on 61-72-month-old preschoolers' early academic and language skills

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Pattern activities have a crucial role in supporting early academic and language skills related to cognitive development, as they play a key role in understanding mathematical ideas and relationships, and in understanding the order, logic and concepts of mathematics. From this point of view, the research was conducted to investigate the effect of the Pattern-based Mathematics Education Program on the early academic and language skills of 61-72-month- old preschoolers. Quasi-experimental design with pretest-posttest control group was used in the study. Forty children, 20 for the experiment and 20 for the control group, constituted the sample. In the experimental and control groups, there were 61-72-month-old children who had not received any special mathematics education and were showing normal developmental characteristics; while attending one of the pre-school education centers in two different campuses of a public university in Besiktas and Esenler districts in the city of Istanbul, Turkey. In the study, General Information Form and Kaufman Survey of Early Academic and Language Skills" were used as data collection tools. A total of eight weeks 'Pattern-based Mathematics Education Program' was applied to the children in the experimental group, five days a week. Kaufman Survey of Early Academic and Language Skills was administered as pre-test and post-test to the experimental and control groups. The same test was given to the experimental group as retention test three weeks after the post-test. In this study, which was limited to the activities presented in the Pattern-based Mathematics Education Program, it was determined that the Pattern-based Mathematics Education Program was effective in supporting the early academic and language skills of 61-72 month old preschoolers.

Key words: Pattern skills, early academic and language skills, early mathematics education, early childhood education.

INTRODUCTION

The essence of mathematics lies in relationships and transformations that lead to patterns and generalizations (Warren, 2005). Mathematics, while investigating and reasoning the accuracy of claims about relations between

objects (Carpenter, et al., 2003), plays a key role in finding out the pattern, mathematical ideas and relationships while providing and understanding of the order, logic and concepts of mathematics (Burns, 2015; Hargreaves et al., 1998). Therefore, mathematics can be named as the science of patterns (Lan-Ma, 2007). Pattern has been defined as noticeable levels of powerful arrangements with numbers, words and figures (Birken and Coon, 2008); the number associated with each other is defined as the fact that space or measurement variables contain predictable regularity (Mulligan and Mitchelmore, 2013). At this point, patterns emphasize the existence of an order and rule in mathematics (Billstein et al., 2016).

The patterns are grouped into three main categories: repeating, growing and relationship (Smith, 2009). Repeating patterns are divided into three groups: linear, circle and hopscotch (Papic, 2007). The changing patterns are grouped in three ways as fixed, increasing and decreasing (Olkun and Yeşildere, 2007). On the side of individuals, patterns are discovered in four stages: recognizing the pattern, defining the pattern, continuing the pattern and producing a new pattern as the final stage (Copley, 2000; Smith, 2009). Steps such as recognition, continuation and creation of patterns are very important capabilities in seeing mathematical relations, making generalizations and understanding the layout of mathematics (Burns, 2015). For this reason, the National Council of Teachers of Mathematics [NCTM] (2000) suggests that children should be able to make advanced generalizations by emphasizing the development of reasoning in terms of geometric and numerical patterns, and to make pattern activities in which they can present patterns in verbal, tabular and graphical form. In Turkey, the Ministry of Education Pre-School Education Program (2013) children are expected to gain skills in supporting their cognitive development by "creating a pattern with models looking at the object, saying the rule in the resulting pattern of at most three elements, saying the item left missing in a pattern, completing or creating a unique pattern with objects". Papic et al. (2011), in their study investigating the patterning strategies of children from 3 years and nine months to five years of age, found that children were successful in recognizing patterns in various spatial patterns even at very young ages. In early childhood, children can easily participate in pattern activities in mathematics, science, music, movement and art sessions by using real objects, themselves and pattern cards; thus they gain experience in patterns. With the help of such process, children are able to notice, identify, continue the existing pattern and produce a new one (Charlesworth and Lind, 2007; Copley, 2000; Smith, 2009).

If children experience the activities related to the pattern from the early period, it can be seen that they begin to perceive patterns indirectly around two years. They can define simple patterns at the age of three and can place the appropriate element to the space in the repeating pattern of two units. At the age of four years, two-unit repetition pattern can be copied and expanded without looking at the model. They can expand simple repetition patterns at five years of age. At the age of six, they define the smallest repeating unit in the repeating pattern, and at seven years of age, they can explain the number patterns and translate it into geometric or numerical representations (Sarama and Clements, 2009). This developmental process also contributes to the development of algebraic and functional thinking in children (Copley, 2000; Smith, 2009). Pattern activities also contribute to the development of skills such as sequencing, and basic numerical processing (Papic and Mulligan, 2005) and in the development of cognitive abilities such as reasoning, communication, association and problem solving (Papic and Mulligan, 2005; Warren and Cooper, 2006). Children explore mathematical concepts while working with pattern activities (Charlesworth and Lind, 2007; Copley, 2000) and can judge the relationship between variables in patterns (English, 2004). Apart from these, the patterns also provide a sense of number. Repetition patterns are seen as a prerequisite for number theory and generalization (Smith, 2009). A child who perceives the repetition unit can start the algebra, which is isolated from a concrete situation, by analyzing the numbers and the relations between them (Charlesworth and Lind, 2007; Copley, 2000; Smith, 2009). Since algebra studies of numbers and arithmetic can improve both the arithmetic and algebraic reasoning of children, it can facilitate the development of a positive tendency for mathematics problems from early ages (Diezmann et al., 2001). Therefore, the importance of patterns in the discovery and understanding of mathematical concepts in pre-school period is great.

In the context of early literacy skills that constitute another sub-field of academic skills, skills such as verbal language skills and articulation, alphabet knowledge, phonological awareness and writing skills are included (Neuman and Dickinson, 2002). In the definition of patterns, there is an identification status with the process of auditory, visual and psychomotor discovery (Charlesworth, 2000: 190 as cited in Waters, 2004). Specifically, the identification of patterns with the audio-visual and visual exploration process can be considered within the scope of early literacy skills. Music patterns in the form of lullabies, lyrics or melodies created in line with the successive sounds or words within the patterns (Geist et al., 2012) can support the increase in children's capacity to understand patterns not only visually but also auditory (Zentner and Eerola, 2010). Regular repetition of lullaby, rhyme, lyrics or melodies can improve children's various concepts, affective and language development, and motor skills (Gök Çolak, 2016). Considering the concept of pattern as an intertwined concept of music and using music patterns in mathematical pattern studies

(Edelson and Johnson, 2003; Geist et al., 2012; Zentner and Eerola, 2010) can help children's development of their basic sound, intonation and rhythmic vocabulary. In addition, children gain intonation and rhythm skills in parallel with the development of speaking, listening, speaking, reading and writing skills (Etopio, 2009).

In the literature, it is observed that researches with preschoolers in terms of pattern skills are rare; nevertheless, Papic (2007) found that most of the children were able to construct, expand, describe, and verify patterns because of the interviews with children who had been attending to kindergarten for two years and had never experienced any growing patterns. Papic (2015) developed the Early Mathematical Patterning Assessment (EMPA) scale which aims to measure mathematical thinking and patterning skills of children aged between four and five years. Warren (2005) aims to reveal how young children generalize repeating and changing patterns and how they symbolize these generalizations. On the other hand, Kesicioğlu (2013) examined mathematical pattern skills of preschoolers in terms of various variables. In addition, two studies investigating the effect of educational activities related to the concept of pattern including games and books in order to increase the level of knowledge and experience of preschoolers in terms of pattern skills were found (Gök-Çolak, 2016).

While there are studies examining patterns and supporting early language skills and academic achievement, no studies in Turkey have been found specifically examining the impact of pattern activities on preschoolers' academic and language skills addressing these skills as a whole. In recent years, the study of alternative approaches to support early academic and language skills and deficiencies in the creation of pattern-based educational programs reveal the importance of this research. At the same time, it is thought that pattern-based mathematics education program will be helpful in giving teachers a different perspective and will contribute to the studies in this field. In this context, the main hypothesis was determined in this study, which was conducted to investigate the effect of the Pattern-based Mathematics Education Program on early academic and language skills of 61-72 month old preschoolers:

"Is there a significant difference (p<0.05) between the children in the experimental group in which the Pattern-based Mathematics Education Program is applied and the posttest scores of the children in the control group in which the current education program is applied in terms of vocabulary, numbers, letters, words and articulation subtests"?

METHODOLOGY

Research design

In order to investigate the effect of Pattern-based Mathematics

Education Program on early academic and language skills of 61-72 months old preschoolers, quasi-experimental design with pretest-posttest control group was used. Since it is difficult for children to be assigned to groups as neutral in educational settings, quasi-experimental designs are preferred in which groups can be matched from certain variables (Gay et al., 2005). Therefore, quasi-experimental design was used in this study. In the study, 2x3 mixed patterns including pre-test, post-test and retention test were used with the experimental and control groups. In the mixed design (Split-plot factorial design), there are at least two variables of which effect is examined on the dependent variable. One of them defines the different experimental process conditions formed by the neutral groups and the other defines the repetitive measurements of the subjects at different times (pre-test, post-test, retention test) (Büyüköztürk et al., 2011). In this study; between-groups variable defines "experimental and control groups" within-groups variable defines "pre-test, post-test, retention tests".

Sampling

In the study group of the research, the preschool education institutions of the universities were listed first. The schools in the list were examined by the researchers and interviews were made with the school administrators and kindergarten teachers and information was taken on whether a special training program was applied on any subject. According to this, preschool classes on which no specific education program had been implemented were listed. In addition, care was taken to ensure that the children included in the study group were willing to participate in the study by obtaining parental consent. According to this, K1 Preschool Education Unit, which is not included in any education program determined by purposive, sampling method, which is in the campus of a state university volunteering to participate in the research, as experimental group. The K2 Preschool Education Unit, located on the other campus of the same university, was also selected as the control group. The study group included 20 children (6 girls-14 boys) in the experimental group and 40 children (11 girls- 9 boys) in the control group.

In the research, 30% of the children in the experimental group were girls and 70% were boys; 35% were first child, 15% were the middle child, 50% were the last child. It is seen that 35% were the only child and 65% had 1-4 siblings. 55 and 40% of the parents of the children were 39 and under, respectively; 45 and 60% were 40 and over, respectively. Twenty percent of parents had high school and lower degree, 35% had bachelor's degree and 45% had master's degree.

Fifty-five percent of the children in the control group were female and 45% were male. It was seen that 50% were the first child, 5% were the middle child and 45% were the last child. Sixty-five of the parents and 55% of the parents of the children were 39 and under; 35 and 45% were 40 and over. Twenty-five of the mothers of the children had high school or lower degree, 65% had bachelor's degree and 15% had master's degrees, while 25% of the fathers of the children in the control group had high school and lower degree, 55% had bachelor's degree and 20% had master's degree.

In order to test the effectiveness of the method / program applied in experimental studies, it is necessary to determine whether there is a significant difference between the groups in terms of the effect of the groups on the effect investigated (Heppner et al., 2008).

Table 1 shows that there was no statistically significant difference according to the results of Kaufman Survey of Early Academic and Language Skills of children in the experimental and control groups as pre-test: Vocabulary (U = -0.628, p> 0.05), Numbers, Letters, Words (U = -0.177, p> 0.05) Articulation Survey (U = -0.163, p> 0.05), K-SEALS (U = -0.136, p>0.05). According to this result, it can

Table 1. Mann Whitney U Test Results Regarding the Difference Between the Pre-test Scores of the Experimental and Control Groups

K-SEALS	Mann Whitney U test						
	Group	n	$\overline{X}$	sd	Mean Rank	U	p
Vocabulary	Experiment	20	25.85	2.37	19.35		
	Control	20	26.1	3.06	21.65	-0.628	0.53
	Total	40	25.98	2.7			
Numbers, Letters and Words	Experiment	20	12.7	4.69	20.83		
	Control	20	12.05	3.35	20.18	-0.177	0.86
	Total	40	12.38	4.04			
Articulation Survey	Experiment	20	15.25	3.71	20.8		
	Control	20	15.15	3.6	20.2	-0.163	0.871
	Total	40	15.2	3.61			
K-SEALS Total	Experiment	20	53.8	8.43	20.75		
	Control	20	53.3	7.38	20.25	-0.136	0.892
	Total	40	53.55	7.82			

*p<0.05.

be said that the experimental and control groups had similar characteristics in terms of early academic and language skills. This also shows that the experimental and control groups were homogeneous.

Data collection tools

In the study, in order to collect demographical information about the children "Personal Information Form" and Kaufman Survey of Early Academic and Language Skills (K-SEALS) to test the children's early academic and language skills were used.

Personal information form

In order to collect personal information about children, a personal information form, which was developed by the researchers, was used to collect information such as birth date, gender, number of siblings, age of parents, and level of education. Personal information forms were filled by the researchers for each child depending on the information in the personal development files of the children in schools.

Kaufman survey of early academic and language skills - K-SEALS

Kaufman Survey of Early Academic and Language Skills original form was developed by Kaufman and Kaufman (1993) and provides assessment of early language, cognitive competence and academic skills of children aged 36-83 months. K-SEALS consists of three sub-tests, four sub-tests, and an Early Academic and Language Skills Composite, which includes the children's early academic and language skills, Word Knowledge, Numbers, Letters and Words and Articulation Survey. It is applied in a quiet and comfortable environment. When the test is applied, each item illustration in the easel is shown to the children, the instruction of the item is read aloud and expected to be answered by the children. For each

correct answer, one score is recorded in the test registration form and zero (0) point for each incorrect answer. The test consists of 90 items and it took 15-25 min for each child to apply. The raw score for each subtest is the number of items correctly answered (Kaufman and Kaufman, 1993). In Turkey Uyanık and Kandır (2014) adapted K-SEALS according to the Turkish children and confirmatory factor analysis according to the total it was determined the one-dimensional factor structure was verified. The KR-20 reliability coefficient for K-SEALS was found to be 0.971 and the item total correlation coefficient of the majority of the items was at a high level of reliability. The test retest correlation for K-SEALS total was set at .908. The relationship between the two test results was found to be significant at p <0.01 level. The researchers individually in a quiet environment administered the test with each child.

Pattern-based mathematics education program (PMEP)

In the Pattern-based Mathematics Education Program, 61-72-month-old children were taken as a basis to raise awareness about the concept of pattern. The philosophy of the program was primarily based on the different views and approaches of theorists such as Rousseau, Montessori, Piaget, Vygotsky, Gardner, Hebb and Dienes. At the same time, theoretical framework of the education program has been established by taking into consideration the literature related to pattern skills and programs implemented worldwide such as Montessori, High Scope, Regio Emilia, Waldorf and "The Big Math for Little Kids" (Balfanz et al., 2003), "Building Blocks" (Clements and Sarama, 2007), and "Number Worlds" (Griffin, 2004) and the gains and indicators included in Turkish Ministry of National Education Preschool Education Program (2013). Based on this, specific gains related to the pattern and which can be added to the program have been prepared. According to the theoretical framework, the program aims to contribute to the mathematical thinking skills by supporting the children's ability to discover, recognize, copy, find the unit of the pattern, continue the pattern and create a unique pattern. Children's sense of curiosity and discovery, and active participation in the program is considered as a whole including daily life, play and mathematics. This

educational program that allows children discover patterns, repeat basic areas, including changing and relationship patterns and creating various learning experiences with different forms of activities such as number, shape, sound and movement. The activities in the program were prepared from simple to complex, from concrete to abstract, sequential and spiral by focusing on the developmental characteristics of children. In the program, children are encouraged to have an opportunity to gain awareness about the concept of pattern with their senses by discovering, recognizing and understanding the unnoticed patterns around them. At the same time, the implementation of pattern activities for various sense organs allows children to acquire skills such as conversion of patterns to different senses (audio-visual, visual-audio, etc.), as well as inter-dimension transformation (converting the three-dimensional pattern into two dimensions, etc.). Pattern-based mathematics activities are integrated with Turkish, music, play, science, movement, drama, reading, writing and art activities, aiming to improve the awareness of pattern and mathematics that exist in daily life and which are related to other disciplines. In addition, children are given the opportunity to work as individual, in small or large groups. The program was designed in accordance with the mathematical process standards including basic mathematical concepts and skills to be acquired in early childhood and in accordance with the development of cognitive abilities and integrated into Turkish Ministry of National Education Preschool Education Program. The Pattern-based Mathematics Education Program was sent to five field experts and finalized after the scope was validated. Pattern-based Mathematics Education Program consists of materials as follows: program summary, educator resource set, in-class educational activities, parent education activities, evaluation forms. The Pattern-based Mathematics Education Program consists of 40 activities for a period of eight weeks, five days a week. Approximately 20 min were spent for each activity. Twenty activities from the repetition pattern, which the children found easier, 13 activities from changing patterns and 7 activities from the relationship pattern, were prepared by considering developmentally appropriate practices. Within the scope of these types of activities, in 14 activities, there were number patterns, in 14 activities, there were shape patterns, in 12 activities there were sound patterns and in 8 activities there were movement patterns. Therefore, Pattern-based Mathematics Education Program is an educational program that allows children to use all their senses effectively with activities created in different forms, including sound, shape, number and movement. Implementation of pattern activities for various sensory organs allows the acquisition of skills such as changing patterns of different senses (audio-visual, visual-audio, etc.) as well as inter-dimensional conversion (conversion of three-dimensional pattern into two, etc.). For example, the educator prepares a circular track with the help of electrical bands consisting of a rectangle, circle and triangle-repeating units. Here, children are provided with opportunities for recognizing cyclical patterns and the repeating units. The educator asks the children to tell each name when it comes to each shape and to make the same shape with their hands. In this way, children turn patterns into movement as they describe their patterns verbally. In another activity, children are expected to make the pattern drawn on the paper with blocks or legos, wherein the skill of transforming of the two-dimensional pattern to three-dimensional is achieved. The pattern of the activity is given in Figure 1.

After the researchers administered the pre-tests, the teacher of the experimental group applied Pattern-based Mathematics Education Program to the children in order to eliminate the difference between the teacher and the researcher. During the pretest administration, the researchers provided information to the volunteer teacher who was in the experimental group regarding the characteristics of the Pattern-based Mathematics Education Program, gains and indicators in the program, arrangement of the learning environment, learning and evaluation processes in the program and the methods and techniques to be used during the implementation. The activities planned to be implemented were explained to the teacher in the experimental group by the researchers by organizing the educational environment one day in advance and the materials were explained together with their intended use. Furthermore, the teacher was informed about parent involvement activities, evaluation forms and how to implement educational processes. After researchers showed the implementation procedure to the teacher, the teacher was asked to apply the activities according to the steps in order, the activities were re-played under the supervision of the researchers, and it was role-played to be prepared for the actual implementation. The education program was implemented five days a week for eight weeks and feedback was given to the teacher after each application. In the control group, the kindergarten teacher in its natural flow implemented the program by continuing the implementation of the existing education program.

Data analysis

In the study, descriptive statistics such as frequency and percentage were used to evaluate demographic characteristics of children. Due to the normality test [Kolmogorov-Smirnoff (K-S)] of the scores obtained from Kaufman Survey of Early Academic and Language Skills, Mann-Whitney U Test was used for investigating the differences between groups and Wilcoxon Signed Rank Test was used for within group comparisons. While examining the differences between the groups; .05 was used as the level of significance and it was reported that there was no significant difference between the groups in the case of $p > 0.05$.

FINDINGS

The results of the research conducted in order to investigate the effect of Pattern-based Mathematics Education Program on early academic and language skills of 61-72-month-old preschoolers are presented in tables. Table 2 shows that the difference between the pretest and posttest scores of preschoolers attending the Pattern-based Mathematics Education Program in terms of the subtests of Kaufman Survey of Early Academic and Language Skills was significant ($p < 0.05$) as follows: Vocabulary ($z = -3.633$), Numbers, Letters and Words ($z = -2.933$), Articulation Survey ($z = -3.42$) and K-SEALS Total ($z = -3.737$). It is observed that this difference was in favor of the posttest mean scores.

According to Table 3, the difference between the posttest and retention test scores of the experimental group children was not significant ($p > 0.05$) in terms of the subtests of K-SEALS: Vocabulary ($z = -1.457$), Numbers, Letters and Words ($z = -0.208$), Articulation Survey ($z = -0.597$) and K-SEALS Total ($z = -0.879$).

Table 4 shows no significant difference ($p > 0.05$) between the pretest and posttest scores of children in the control group in terms of the subtests of K-SEALS: Vocabulary ($z = -0.745$), Numbers, Letters and Words ($z = -0.592$), Articulation Survey ($z = -1.177$) and K-SEALS Total ($z = -1.07$). When the mean scores of the children in the control group were taken into consideration, there was an increase in the posttest scores. It is thought that this could be due to the result of the acquisition of
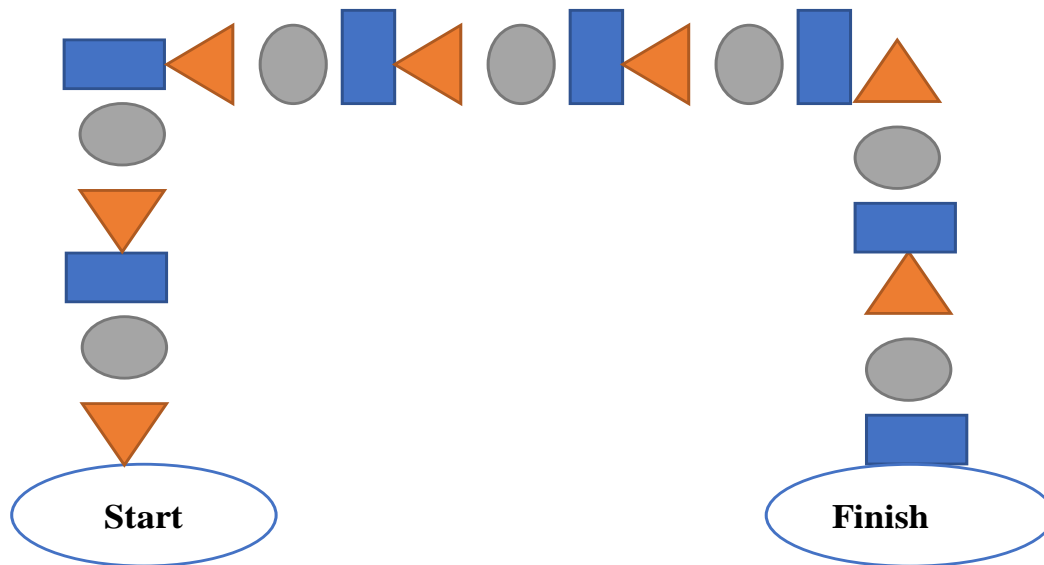
Figure 1. A sample pattern.

Table 2. Wilcoxon signed rank test results regarding the experimental group children's pretest and posttest scores.

K-SEALS	Wilcoxon Signed Rank Test					
	Test	n	$\overline{X}$	sd	z	p
Vocabulary	Pretest	20	25.85	2.37	-3.633	0.0001*
	Posttest	20	28.75	1.65		
Numbers, Letters and Words	Pretest	20	12.7	4.69	-2.933	0.003*
	Posttest	20	16.9	7.1		
Articulation Survey	Pretest	20	15.25	3.71	-3.42	0.001*
	Posttest	20	18	2.87		
K-SEALS Total	Pretest	20	53.8	8.43	-3.737	0.0001*
	Posttest	20	63.65	9.28		

*p<0.05.

cognitive and language development gains and indicators in Turkish Ministry of National Education Preschool Education Program (2013) applied to children and the normal course of improvement in children's academic and language skills during the research process.

Table 5 presents a significant difference in favor of the experimental group when the researchers sought for difference between the posttest scores of children in the study group in terms of the subtests of K-SEALS: Vocabulary (U=-2.442, p>0.05), Numbers, Letters and Words (U=-2.22, p>0.05) Articulation Survey (U=-2.42, p>0.05), K-SEALS Total (U=-2.878, p>0.05). It can be argued that Pattern-based Mathematics Education Program is effective on preschoolers' early academic and language skills in the light of this result.

DISCUSSION

Early learning experiences play a critical role in children's lifelong learning (Clements and Sarama, 2011). Especially short and long-term effects are seen in cognitive and social development of children who are included in qualified education programs in early childhood (Jackman, 2012). The characteristics of pattern functions and algebra are a guiding task for teachers who want to develop preschool class activities that are fun, and children can participate tirelessly (Smith, 2009). Children can develop critical thinking and problem-solving skills when working with pattern activities. At the same time, patterns and relationships are an important concept in understanding and generalizing mathematical thinking

Table 3. Wilcoxon signed rank test results regarding the experimental group children's posttest and retention test scores.

K-SEALS	Wilcoxon signed rank test					
	Test	n	$\overline{X}$	sd	z	p
Vocabulary	Posttest	20	28.75	1.65	-1.457	0.145
	Retention	20	29.3	1.59		
Numbers, letters and words	Posttest	20	16.9	7.1	-0.208	0.835
	Retention	20	16.6	5.96		
Articulation survey	Posttest	20	18	2.87	-0.597	0.551
	Retention	20	18.35	2.43		
K-SEALS Total	Posttest	20	63.65	9.28	-0.879	0.379
	Retention	20	64.25	7.84		

*p<0.05.

Table 4. Wilcoxon Signed Rank Test Results Regarding the Pretest and Posttest Scores of Control Group Children

K-SEALS	Wilcoxon Signed Rank Test					
	Test	n	$\overline{X}$	sd	z	p
Vocabulary	Pretest	20	26.1	3.06	-0.745	0.456
	Posttest	20	26.47	3.44		
Numbers, letters and words	Pretest	20	12.05	3.35	-0.592	0.554
	Posttest	20	12.37	5.2		
Articulation survey	Pretest	20	15.15	3.6	-1.177	0.239
	Posttest	20	15.63	3.15		
K-SEALS total	Pretest	20	53.3	7.38	-1.07	0.285
	Posttest	20	54.47	8.19		

*p<0.05.

and relationships, in developing reasoning skills (Papic and Mulligan, 2005), and in understanding the order and logic of mathematics (Burns, 2015). Patterns include counting and operation skills by their structure and children can use mathematical concepts and develop matching, sorting, grouping and comparison skills (Papic and Mulligan, 2005; Palabıyık and Akkuş-İspir, 2011). In this study, which investigates the effect of Pattern-based Mathematics Education Program on 61-72 month old children's early academic and language skills, a statistically significant difference (p <0.05) was found in favor of the experimental group. This was so when the researchers compared the posttest results of Kaufman Survey of Early Academic and Language Skills (Vocabulary, Numbers, Letters and Words, Articulation Survey and K-SEALS Total). Other independent variables, which were not observed and/or controlled by

the researchers prior to the implementation, might have contributed slightly to this finding but this is the case for the quasi-experimental design (Cook and Campbell, 1979). In the case of the control group, there was no statistically significant difference (p>0.05) between the pretest and posttest scores of the Kaufman Survey of Early Academic and Language Skills (Vocabulary, Numbers, Letters and Words, Articulation Survey and K-SEALS total). In this study, which is limited to the number of children in the study group and activities in the Pattern-based Mathematics Education Program, it was found that the Pattern-based Mathematics Education Program was effective in supporting the early academic and language skills of 61-72-month-old preschoolers.

In Pattern-based Mathematics Education Program, there were efforts to provide enriched environments for children, to ensure active participation, to have activities

Table 5. Mann Whitney U test results regarding the difference between posttest scores of children in the control and the experiment groups.

K-SEALS	Mann-Whitney U Test						
	Group	n	$\overline{X}$	sd	Mean Rank	U	p
Vocabulary	Experiment	20	28.75	1.65	24.95		
	Control	20	26.45	3.35	16.05	-2.442	0015*
	Total	40	27.60	2.85			
Numbers, letters and words	Experiment	20	16.90	7.10	24.60		
	Control	20	12.30	5.07	16.40	-2.22	0.026*
	Total	40	14.60	6.52			
Articulation survey	Experiment	20	18.00	2.87	24.88		
	Control	20	15.75	3.11	16.13	-2.42	0.015*
	Total	40	16.88	3.16			
K-SEALS total	Experiment	20	63.65	9.28	25.83		
	Control	20	54.50	7.97	15.18	-2.878	0.004*
	Total	40	59.08	9.71			

*p<0.05.

to support all developmental domains, to create awareness about the concept of pattern, to associate mathematical concepts with daily life and to discover that mathematics is in every aspect of life. In the program, activities involving all sensory organs and the ability to find the logical relationship between words, classification of objects, concepts or events, cause-effect relation, the ability to see the relationship between words and sentences, and find the logical relationship between words, especially given the children in sound (music) patterns classifying the elements in the pattern. This established the cause-effect relationship and exploring the logical relationship in the elements of the pattern, making activities to generalize the pattern have an effect on the development of early academic and language skills of the children in the experimental group. At the same time, the integration of activities in the program with fields such as science, art, music and games and the inclusion of pattern forms for all sense organs can be considered as the reason for this result.

Parallel findings have been reported in the literature. For example, Gök-Çolak (2016) found that the Pattern-based Mathematics Education Program had a positive effect on verbal and numerical reasoning skills of 61-72-month-old children. Papic (2007) found that a six-month early intervention program focusing on repetitive, spatial patterns had an impact on children's early number skills. Mulligan et al. (2008a) found that the PASMAP (Pattern and Structure Mathematics Awareness Project) project, which was related to the concept of pattern and the place of pattern and algebra in mathematics programs, contributed positively to children's mathematical skills.

Rittle-Johnson et al. (2016) pointed out that early repeating patterning activities predicted children's mathematics knowledge and development. Recently, as an outcome of the longitudinal studies carried out by Nguyen et al. (2016) and Rittle-Johnson et al. (2017) it was stated that working with repeating patterns in early childhood predicted children's mathematics achievement at fifth and sixth grades. Likewise, it has also been reported that awareness raising on patterns and relationships were positively correlated with mathematical achievement (Booth and Thomas, 2000; Mulligan and Mitchelmore, 2009), analogical reasoning (English, 2004), mathematical reasoning (Mulligan et al., 2008b; Papic, 2015; Warren and Cooper, 2008). In addition, it was found out that pattern awareness in children influenced the understanding of number concepts and processes such as counting, distribution and numbering (Mason et al., 2009; Thomas et al., 2002).

On the other hand, Kidd et al. (2013) carried out a research on a pattern-based education program for elementary school students and concluded that the subjects benefited highly from the education while Kidd et al. (2014) reported that patterning instruction had large, fully mediated effects on both reading and mathematics in their research on the first graders.

Considering the concept of pattern as a nested concept of music and using music patterns in mathematical pattern studies (Edelson and Johnson, 2003; Geist et al., 2012; Zentner and Eerola, 2010), it has been reported that it children's vocabulary enhanced (Moyeda et al., 2006). In addition, developments were seen in language skills (Marin, 2009), phonological awareness, vocabulary,

semantics, syntax and phonetics (Curtis, 2007) when children participated in activities including rhythm, songs and games. These studies are likely to support the idea that Pattern-based Mathematics Education Program affected children's acquisition of skills related to vocabulary, articulation and phonology.

Conclusion

In the light of the conclusions we draw from our findings, the following implications may be presented:

(i) Policy makers, teacher training institutions, researchers, preschool teachers and parents should work together to understand the importance of early academic and language skills in preschool period. In this regard, policy makers and universities can support projects aimed at increasing children's relevant knowledge and skills.
(ii) Pattern-based Mathematics Education Program can be integrated into Turkish Ministry of National Education Program in accordance with all age groups.
(iii) In line with the principles and characteristics of the Pattern-based Mathematics Education Program, interdisciplinary studies can be conducted based on holistic development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Bibliometric analysis of the studies in the field of mathematics education

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The purpose of this study is to perform bibliometric analysis of the scientific researches published in mathematics education subject area between 1980 and 2018, to find out the general layout of the scientific knowledge and communication structure of the field using an objective method, driven from the data. The publications were analyzed according to publication year, type of publication, language of publication, title of publication, name of the author, country of the author and number of citations taken from the sources scanned in Web of Science (WoS) Core Collection database; structural and temporal analysis of various networks, such as collaboration networks and author collaborations were performed. In addition, a word analysis was also conducted in the study to determine the concepts used in the researches published in mathematics education area and covered in the data set. It was found that the publications involving mathematics education increased from 1980 to 2018. The review of the countries according to the number of studies that they have performed in the field revealed that the most productive countries are United States, England and Turkey. Regarding the centrality of the countries in the network, the countries that are located at the center of the network were found to be England, US and Spain, respectively. Regarding the ranking of the countries according to the number of citations taken for the scientific works that they have performed in mathematics education area, it was found that US, Turkey and Malaysia had the highest number of citation bursts. Regarding the ranking of the works according to title, the topics that have been mostly worked on are elementary mathematics classroom, teacher education and achievement gap. The words that are mostly used in mathematics education research area were mathematics, education, student and achievement, respectively.

Key words: Social network analysis, bibliometric analysis, mathematics education, scientific knowledge, scientific communication.

INTRODUCTION

In today's world, which is dominated by technology, many national and international scientific researches, reviews and studies are performed in mathematics education area, as in the other disciplines. The variations that have

occurred in the content of the courses based on the developments in science revealed different views about the needs of a developing society and how mathematics instruction should be done to achieve a

more effective mathematics education. Analyzing the trend of recent researches performed in mathematics education will guide the researchers and educators for scientific debates and queries, as well as illuminating short, middle and long-term studies (Milli, 2018).

The researches show that the achievements in mathematics education can be enhanced through new approaches. A student-centered mathematics education approach, performed in an environment where students can express their thoughts freely, develop their reflection strategy, and well-connected with daily life is expected to contribute to rising individuals who are capable of thinking mathematically and solving problems (Umay, 1996).

As a natural result of the changes and regulations realized in mathematics education programs, changes occur in the roles of teachers and students in education. New programs outline the roles of the teachers not only as planning activities, but also as "questioning, listening, guiding, motivating and making students ask questions, think and discuss"; whereas they define students as individuals who are capable of "asking questions, querying, developing their own problems and solving them, thinking, discussing and working together". The changes and improvements in the curriculums help to proceed on enhancing the quality of the education and solving various problems that are present in the education system (Arslan and Özpınar, 2008).

Social network analysis is an inter-disciplinary research area built on various disciplines, including sociology, anthropology, statistic, and mathematics (Van and Vermunt, 2006). With the improvements in the content of social network analysis (foundation based on 1960s), in recent years, it became one of the working areas often talked about. Social network analysis aims to explain, visualize and understand the network structure obtained from the relationships among individuals through statistical modelling. As in the other disciplines, social network analysis is widely used in education as well (Carolan, 2013; Scott, 2017). The most significant feature of this approach focuses on the relationships between individuals and social units, rather than these entities themselves (Martino and Spoto, 2006). Social network analysis is also used to determine the significant actors in a research community through the visualization of collaboration and common citation networks, in addition to identify information networks that are effective on the development of the research area (Yüncü and Karagöz, 2013). The visualization of social networks is quite important in terms of understanding social network data and interpreting analysis results. Most of the software developed for this purpose use different modules for the visualization of the network. Bibliometric analysis method is one of the tools used to see overall picture of a field, to analyze the scientific works published in this area and to interpret the results both statistically

and visually.

Bibliometrics involves the quantitative analysis of certain characteristics of the publications or documents, including author, subject, publication information, cited sources, etc. It is possible to investigate how scientific communication process occurs using obtained bibliometric data (Güzeller and Çeliker, 2018). Bibliometric studies allow the identification of the trends in a certain field by quantifying the literature in this area (Kasemodel et al., 2016). In bibliometric researches, the works are analyzed according to certain characteristics and various findings are obtained (Al and Coştur, 2007). Citation analysis performed in bibliometric studies allows the assessment of the qualities of scientific publications. Most important data sources of bibliometric researches are international scientific citation indexes, including Science Citation Index (SCI), Social Science Citation Index (SSCI) and Art & Humanities Citation Index (A&HCI), which are being accessed through Web of Science (WoS) Core Collection database. WoS makes significant contributions to bibliometric works as a database hosting bibliometric data concerning the publications scanned in these indexes (Güzeller and Çeliker, 2017). Within the scope of the study, we attempted to review all works concerning mathematics education, published in WoS database between 1980-2018; to identify the authors and journals that have performed important works in mathematics education area from past to present; and to reveal popular topics according to years. In addition, the effect of country variable on the performed works was investigated by identifying the countries of the researchers who have worked on mathematics education area.

Problem statement of the research

What are the authors, journals, countries and topics that have been effective in mathematics education field between 1980-2018?

The following sub-problems were also addressed within the scope of the study:

1. Regarding the number of academic works realized in mathematics education area, what are the most productive countries in terms of total number of publications?
2. Regarding the number of citations taken from the scientific works, what are the countries with the highest citation bursts, that is attracting an extraordinary degree of attention from its scientific community?
3. What are the works that get the highest number of citations from the studies included in the data set?
4. What are the most frequently used keywords in the studies published in mathematics education research

area?

5. What are the concepts that are most frequently used in the studies published in mathematics education research area?

Bibliometric researches conducted in mathematics education area

Regarding the bibliometric studies in the literature, there are numerous national and international studies assessing the articles published in the journals, master thesis, papers presented in the congress and symposiums. On the other hand, it was observed that there are few bibliometric studies performed in mathematics education area.

In his thesis, Yücedağ (2010) has analyzed 390 postgraduate theses performed in mathematics education area, and 153 articles published in 4 Turkey-centered journals between 2000-2009. As a result of the analysis, the terms mostly used in research titles were found to be "instruction methods" for the theses and "affective dimension" for the articles. The subtitles that have been used most in both theses and articles were found to be "attitude" and "problem solving", whereas the titles that have been least worked on were "motivation" and "habit". The methods than have been mostly used in the theses were experimental research, content analysis and literature review, whereas collection was the least used method. The methods mostly used in the articles were respectively experimental, literature review and content analysis, whereas book review was the least used method. The researcher has stated that geometry and algebra were mostly studied topics in theses, whereas articles mostly focused on algebra.

In his thesis, İlhan (2011) worked on 124 national postgraduate theses, 219 national and 356 international articles published between 2005-2009 in mathematics education area and he revealed their distributions thematically, methodologically and in terms of statistical analysis techniques. A total of 343 national and 356 international works have been analyzed using Academic Publication Assessment Form, developed for this purpose. Thematically; a tendency towards cognitive area was observed in international studies, whereas works concerning instruction strategies, teaching methods and techniques, along with achievement were more popular in national studies. Methodically; international researches were concentrated on literature reviews and studies concerning teachers, in national studies experimental researches and studies having samples from elementary education 2nd level students were more prevalent. In terms of statistical techniques: descriptive statistics, t-test, ANOVA were the techniques frequently used in both groups. Constant comparison, Kruskal Wallis-H, regression, discourse analysis and multiple regression were other techniques preferred in international studies.

In his paper, Yılmaz (2011) has analyzed 82 articles published in Elementary and Secondary Mathematics Education Area, in Hacettepe University Education Faculty Journal, from 1988-2010. In his work, the articles were classified according to their sample compositions, divided into certain categories for each sample, the themes were formed and combined with other samples. The findings were obtained after performing content analysis on the articles. As a result of the research it was found that: numerous researches have been conducted in teaching-learning area; these researches have been mostly concentrated on active mathematics learning; when analyzed a little more specifically, it was found that many factors, such as method, technique, and environment have affected this fact and they have been affected by this fact. In addition, it was found that researches have been conducted in many areas, including mathematic-language, achievement, nature of mathematics, gender, cognitive and inherent factors and these works have moved mathematics education one step ahead.

Yaşar and Papatğa (2015) have analyzed 50 postgraduate theses concerning elementary school's mathematics courses performed from 2002-2012, through qualitative research method. Data were collected via document review and the theses were analyzed according to: the postgraduate level that they were performed, university and discipline, title of the advisors who undertook execution responsibility, year of preparation, class level of the primary school where the study was realized, selected subject area, selected topic, research methods, data collection techniques and data analysis methods. Research data were analyzed using content analysis. As a result of the research it was found that; most of the prepared theses were postgraduate, most of the theses were performed in 2010 and 2011, at 5th grade level, mostly assistant professors participated as advisor, mostly performed in algebra subject area, quantitative research method was frequently used, achievements test was mostly used as data collection technique, and t-test was employed in quantitative data analysis.

Çiftçi et al. (2016) aimed to perform citation analysis to the scientific journals published in educational science field in Turkey and determine their impact factors. For this purpose, a comprehensive citation analysis was performed with over 7,681 articles, published in 32 scientific journals with reviewer; then impact factors of each journals were identified. SPSS, NVivo, Excel and ESOGU-BAAP software, developed for the research, were used in the bibliometric and citation analysis of the articles. Regarding the articles analyzed within the scope of the research, top three most cited journals were found to be (i) Hacettepe University Education Faculty Journal, (ii) Educational Sciences in Theory and Practice and (iii)

Ankara University Educational Sciences Faculty Journal. Regarding 2014's impact factor coefficient of the journals covered within the scope of the research, the journals with the highest impact factor coefficient were found to be (i) Educational Sciences in Theory and Practice, (ii) Educational Management in in Theory and Practice and (iii) Theoretical Education Science Journal.

METHODOLOGY

In this study, scientific studies published in mathematics education area and included in Web of Science (WoS) database were analyzed using bibliometric analysis method. In this scope, this study was performed within the frame of descriptive analysis, using document review method (Güzeller and Çeliker, 2018). Since the study aims to describe current situation, it can be accepted as a study of scanning model type (Franken et al., 2012).

Data collection process

In this regard, Web of Science database was scanned for "mathematics education" keywords to obtain the data of the research. As a result of the scan performed in Web of Science in the time interval set as 1980-2018, a total of 9,841 scientific researches were found.

14,831 scientific records were reached in the period of 1980-2018 in mathematics education in the Web of Science. As some of these records contain studies related to different disciplines, the records are limited to the topics of education, educational research, education scientific disciplines, and special education. In this context, 9,941 scientific records were provided which provide the inclusion criteria.

Data analysis

Citespace II, which is a social network analysis software, was used to determine the concepts used in mathematics education area; to find out the countries of the authors who led the researches; to identify the authors, works and the journals in which these works were published; and to visualize the relationships among them. Citespace II is a Java application used to visualize and analyze the trends and changes occurring in a scientific area or topic (Chen, 2006). This software performs structural and temporal analysis of various networks obtained from scientific publications, such as collaboration networks, author associations (Synnestvedt et al., 2005).

In order to start the analysis, all bibliometric data, including author name, title, source of the documents, publication year, title of publications, number of citations, citation and type of the article were collected in electronic format and saved as text document (with .txt extension). Data were downloaded as batch of 500 files in .txt format and loaded to Citespace II software, which united these files and analyzed as a single data file. Data files to be analyzed were introduced into the program; the time period was defined; "cited references", "cited author" and "cited journal" options were activated. The results obtained from Citespace II software were displayed in two different forms (time zone and cluster view). In time zone view, the change of common citations over time was visualized, whereas in cluster view, cluster divisions obtained from common citations in the defined time zone were visualized. Analysis results were separately reported in the form of cluster view and time zone view. In Citespace program, the names of critical authors, journals and countries are represented by circle, line or color. The circle around the author, journal or country indicates the citation history of a particular reference, whereas the thickness of the circle shows the number of citations over a defined time period. Bigger circles indicate higher number of references. The line between two circles indicates common reference sources present in both citations. The thickness of this line shows the strength of the common citation, whereas its color indicates the time of the common citation (Liu and Shen, 2013).

During the analysis, the contributions of the authors connected with different countries were computed separately to determine countries' overall productivity. In the cases where the authors stated two different institutions and countries due to performing researches in two different institutions, located in different countries, the country stated in the first place was included in the analysis unit. While performing the analysis, if a publication contained two or more authors from the same country, the country was counted once.

FINDINGS

Distribution of publications according to years

As a result of the scan performed with math education/mathematics education keywords, 14.831 scientific records were found to be published from 1980-2018. In order to prevent the same study to be present twice in the scans performed with both keywords and to eliminate the possibility of including the same study twice in the analysis, data were downloaded from Web of Science in excel format. It is possible to download various information from Web of Science in excel format, such as the titles of the works that will be used in the data, their authors, publication years, the journals in which they were published, volume number and pages. In this regard, the titles of the works obtained from both keyword scans were alphabetically sorted in excel and one of the studies found to be identical were excluded from the analysis. 9.841 individual studies were found and their duplications were removed from the data. In other words, double-counted studies were counted once while calculating the number of publications. In addition, one of the double-counted studies was removed while loading them to Citespace software; therefore country, common citation and word analysis remained unaffected from double-counted studies.

Since some of these records covered the studies from different disciplines/themes, for the sake of the research objective, the records were limited with education, educational research, education scientific disciplines, and special education themes. Within this scope, the analyses were performed on 9.841 scientific records that fulfilled inclusion criteria (Figure 1).

Regarding the distribution of the publication according to defined time periods, it is seen that the number of publications increased in each period. It can be seen that the highest number of publications was realized between
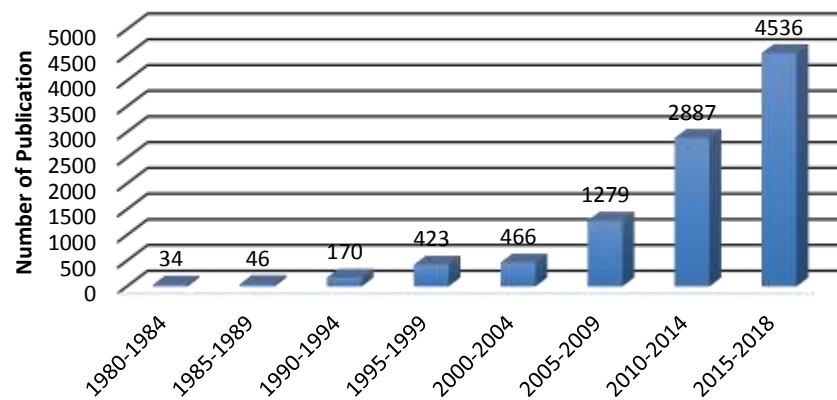
Figure 1. Distribution of the Publications according to time periods.

Table 1. Frequency values and centrality degrees of the countries.

Number of citations	Countries	Cluster #	Centrality	Countries	Cluster #
4073	USA	0	0.31	ENGLAND	4
569	England	4	0.30	USA	0
520	Turkey	0	0.17	SPAIN	1
467	Spain	1	0.14	NETHERLANDS	3
405	Australia	0	0.09	GERMANY	2
379	Germany	2	0.08	FRANCE	2
337	Canada	2	0.07	AUSTRALIA	0
258	Netherlands	3	0.05	CHILE	1
216	South Africa	2	0.05	BRAZIL	1
198	Peoples R China	0	0.05	SWEDEN	2

2015-2018 (46.1%) (n=4,536). The publications made in 2010 and after constitute 75.4% of the whole publications. Since this result covers the period that our study is being performed, it can be said that the number of publications in 2018 is expected to increase.

Countries that have contributed to the field

A network analysis was performed to determine the countries of the authors that have made the biggest contributions to mathematics education area in terms of scientific work. The network obtained as the result of the analysis consists of 78 nodes (countries) and 393 connections (relationship between countries). The network was divided into 14 clusters; its density was calculated as 0.13, where network density shows the ratio of the connections used in a network and the number of potential connections (Al and Doğan, 2012: 354). Q modularity value of the network was found to be 0.24, where Q modularity takes a value between 0-1 and

the values closer to 1 signify closer relations and connections within the cluster. Usually Q modularity values between 0.4-0.8 are accepted as the indicator of a good clustering. Mean silhouette value was 0.17, where mean silhouette value takes a value between -1 and 1 and the values close to 1 signify that the factors in the network are consistent and similar (Güzeller and Çeliker, 2018; Li et al., 2017; Zhang et al., 2015).

The most productive 10 countries of the network are shown in Table 1, with their frequencies. In addition, top 10 countries having the highest centrality values are also displayed in Table 1. The countries having 100 or more frequencies are included in the network and the purple circle in the network indicates the countries with high centrality (Figure 2).

Regarding the number of publications of the countries in mathematics education area, US was found to be the most productive country with 4,073 academic works, whereas England is the second most productive country with 569 works and Turkey is the third most productive country with 520 works. While determining country

Figure 2. Countries that have contributed to the field.

Table 2. Citation Burst Values of the Countries.

Countries	Strength	Begin	End	1980-2018
USA	110.64	1980	2004	
TURKEY	13.50	2012	2013	
MALAYSIA	12.11	2010	2014	
FRANCE	9.84	2008	2011	
COLOMBIA	7.74	2015	2016	
CHILE	7.21	2016	2018	
CYPRUS	7.12	2008	2010	
ITALY	6.88	2008	2011	
DENMARK	6.13	2010	2011	
BRAZIL	5.78	2009	2010	

productivity, if a publication contained two or more authors from the same country, the country was counted once.

Regarding the centrality of the countries, it can be seen that the most central countries in the network are England (0.31), USA (0.30) and Spain (0.17). It can be said that these countries play an important role in the establishment of scientific communication in mathematics education area and they serve as a bridge.

Regarding the citation bursts calculated according to the number of citations that countries received from the scientific works that realized, the presence of citation bursts were detected for 22 countries and it can be seen that the works performed by the authors of USA have the highest value (110.64) (Table 2). Accordingly, it can be said that from 1980-2004, authors from USA have guided the works that have been performed in the field and they have made significant contributions to the development of the field. Another result is that authors from Chili are frequently referred by the recent works performed in the field.

Publication's Common Citation Network

A network analysis was conducted based on the bibliographies of the studies included in the data set in order to determine the reference sources that were

Table 3. Frequencies of Citation Sources.

CC	References	Year	First Author	Cluster #
161	Content knowledge for teaching: What makes it special?	2008	Loewenberg Ball	1
145	Common Core State Standards for Mathematics (CCSSM).	2010	Common Core State Standards Initiative	1
110	Principles and standards for school mathematics	2000	National Council of Teachers of Mathematics	6
103	Visible learning: A synthesis of over 800 meta-analyses relating to achievement	2008	Hattie J.	1
95	Teachers' mathematical knowledge, cognitive activation in the classroom and student progress	2010	Baumert, J.	1
83	Active learning increases student performance in science, engineering and mathematics	2014	Freeman, S	12
83	Foundations for success: The final report of the National Mathematics Advisory Panel	2008	National Mathematics Advisory Panel	4
77	Effects of teachers' mathematical knowledge for teaching on student achievement	2005	Hill H. C	4
68	Next generation science standards: For states, by states.	2013	National Research Council	1
65	Common core state standards	2010	National Governors Association	1

CC, Citation Counts.

mostly cited in mathematics education area. As a result of the analysis, a network consisting of 1610 nodes (publication), 4395 connections (relationships between publications) and divided into 321 clusters was obtained. The network density was calculated as 0.0034. Its Q modularity value is 0.84, mean silhouette value is 0.26. The colors in the network represent the distribution according to years, whereas red circles show citation bursts. The reference sources included in the network are the ones having 50 or more frequencies and they are shown with green. The topic clusters by references are shown with black. Top 10 sources with highest frequencies are shown in Table 3.

The work that got the highest number of citations from the studies included in the data set is the article titled as "*Content knowledge for teaching: What makes it special?*" (n=161), written by Loewenberg et al. (2008) and published in *Journal of Teacher Education*. The review of top ten works revealed that each of them was published after 2000 (Figure 3). Moreover, it was found that all top 10 works with the highest number of citations belong to the cluster #teacher education, which shows that the works performed in mathematics education area mainly focused on this title.

The analysis of the works according to citation bursts showed that 79 works had citation bursts. The work with the highest citation bursts value is *Content knowledge for teaching: What makes it special?"* (49.50), written by Loewenberg et al. (2008) and published in *Journal of Teacher Education*. This work was frequently referred by the studies performed between 2011-2016 and considering that this work belongs to cluster titled as

#teacher education, it can be said that the works performed between 2011-2016 in mathematics education research area mainly focused on this subject (Table 4). The works performed by *Hattie J (#cluster 1), National Research Council (#cluster 1) and Freeman, S (#cluster 12)* had recent citation burst. Regarding the clusters that these works belong, it can be seen that current publications in mathematics education research area focus on #teacher education and #gendered effect topics.

The most studied topics in mathematics education research area were determined based on the titles of the works cited by the studies included in the data set. As a result of the analysis, a total of 26 titles were found and 8 titles with the highest number of citations are shown in Table 5. The titles mostly studied in the field are elementary mathematics classroom (5661.4, 1.0E-4) and teacher education (2854.99, 1.0E-4). Silhouette values of the clusters indicate a homogenous structure. According to Simovici (2007), silhouette value being higher than 0.7 indicates a strong and homogenous clustering. Regarding average citation year of cluster titles, it can be said that elementary mathematics classroom (1989) and teacher education (2009)] are the titles currently studied in the field.

Word analysis

A network analysis was performed for identifying frequently used words in the works published in the field of mathematics education based on the abstracts and keywords of the publications, and thereupon a network
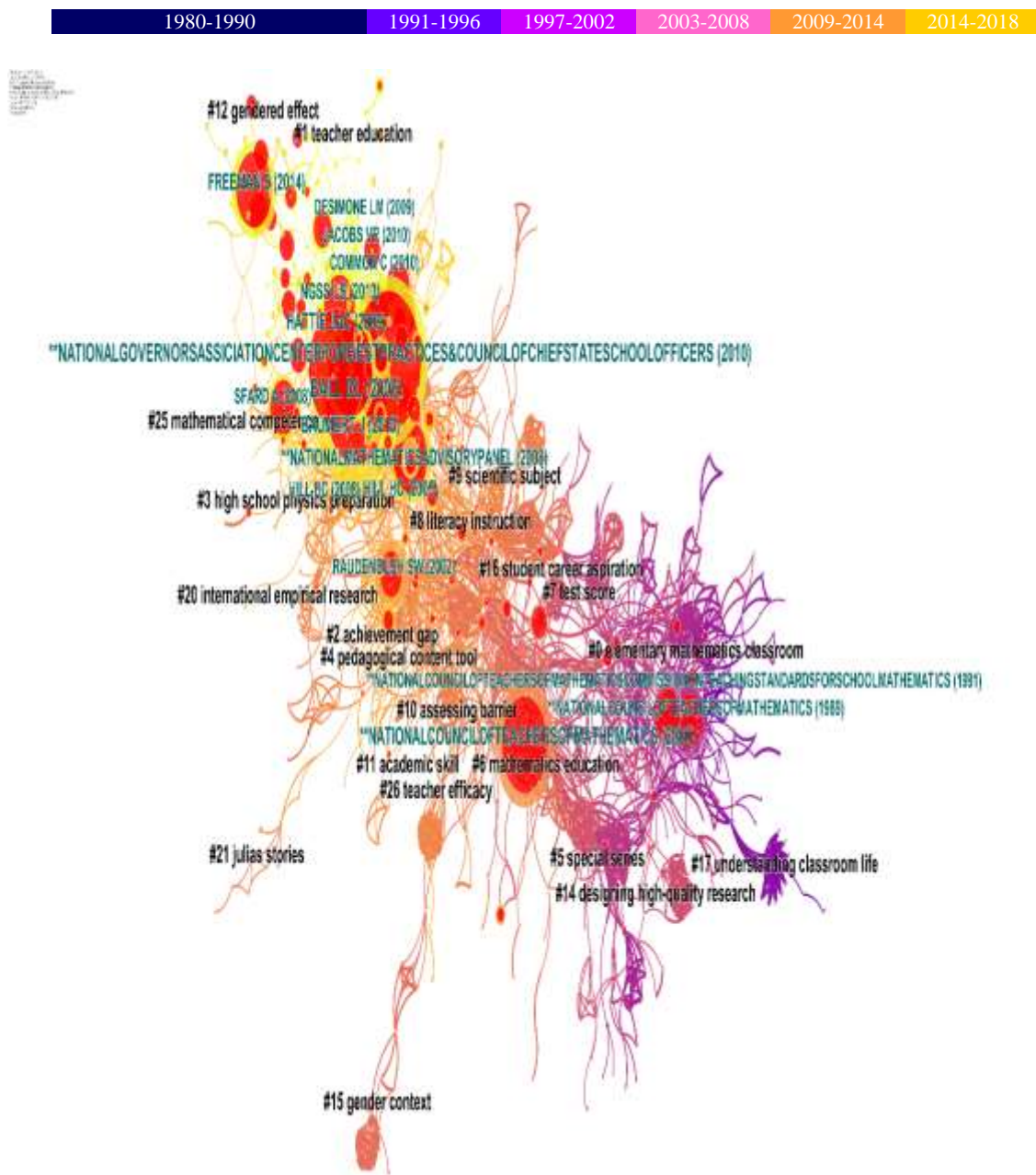
Figure 3. Publication's Common Citation Network.

consisting of 300 nodes (word) and 1,855 connections was obtained. The network density was measured as 0.04, Q modularity value is 0.34 and mean silhouette value is 0.26. The network was divided into 18 separate clusters (Figure 4).

Top 20 words with the highest frequencies, obtained as a result of the analysis, are displayed in Table 6. Accordingly, the concepts that were mostly used in the works performed in the field were identified as mathematics (n=1841), education (n=1732), student (n=919) and achievement (n=893).

Regarding centrality degrees of the concepts, it can be seen that mathematics (0.15), instruction (0.12), model (0.12) and reform (0.12) have the highest centrality. In this regard, it can be said that these concepts have a key role in the studies performed in the field and they are the

Table 4. Citation Burst Values of Citation Sources.

First Author and References	Strength	Begin	End	1980-2018
Loewenberg Ball (2008) Content knowledge for teaching: What makes it special?	49.50	2011	2016	
National Council of Teachers of Mathematics (2000) Principles and standards for school mathematics	49.36	2001	2008	
Common Core State Standards Initiative (2010) Common Core State Standards for Mathematics (CCSSM).	49.36	2001	2008	
National Council of Teachers of Mathematics (1989) Curriculum and evaluation standards for school mathematics.	37.82	1989	1997	
Hattie J. (2008) Visible learning: A synthesis of over 800 meta-analyses relating to achievement	35.18	2013	2018	
Freeman, S (2014) Active learning increases student performance in science, engineering, and mathematics	34.66	2015	2018	
National Research Council (2013) Next generation science standards: For states, by states.	32.87	2016	2018	
National Council of Teachers (1991) Professional standards for teaching mathematics.	30.46	1992	1999	
Raudenbush, S. W. (2002) Hierarchical linear models: Applications and data analysis methods	27.07	2007	2010	
Hill, H. C (2005) Effects of teachers' mathematical knowledge for teaching on student achievement	25.93	2007	2013	

Table 5. Most studied titles in math/mathematics education research area.

Cluster	Size	Silhouette	Label (TFIDF)	Label (LLR)	Mean (cited year)
0	150	0.87	mathematics	elementary mathematics classroom (5661.4, 1.0E-4)	1989
1	123	0.77	mathematics	teacher education (2854.99, 1.0E-4)	2009
2	82	0.79	mathematics	achievement gap (4706.37, 1.0E-4)	2003
3	80	0.82	science	high school physics preparation (2141.43, 1.0E-4)	2006
4	78	0.81	mathematics	pedagogical content tool (3391.47, 1.0E-4)	2005
5	75	0.96	learning disabilities	special series (4157.96, 1.0E-4)	1993
6	71	0.82	students	mathematics education (1162.51, 1.0E-4)	1997
7	68	0.97	effects	test score (2696.79, 1.0E-4)	1994

keywords of the field.

DISCUSSION

In this study, bibliometric analysis of the academic works concerning mathematics education, published in Web of Science database was performed using Citespace II software; outstanding authors, journals, countries and subject fields were determined; and they are visualized graphically and statistically. The study includes 9,841 works published from 1980-2018 in mathematics education area. Regarding the distribution of the publications according to time periods, it can be said that the number of publications has increased in each period. It can be seen that the highest number of publications was realized from 2015-2018 (46.1%). The network analysis performed to determine the countries of the authors that have made the biggest contributions to mathematics education area in terms of scientific work resulted with a network consisting of 78 nodes (countries) and 393 connections (relationship between countries). The network was divided into 14 clusters. The review of the countries according to the number of publications that they have performed in mathematics education area revealed that most productive countries are USA, England and Turkey. While determining country productivity, if a publication contained two or more
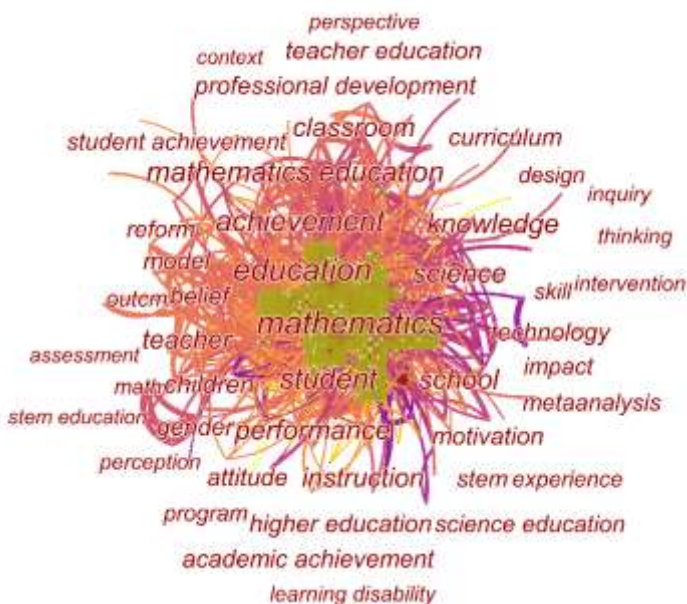
Figure 4. Word analysis.

authors from the same country, the country was counted for once. Regarding the centrality of the countries, it can be seen that the most central countries in the network are England, USA and Spain. It can be said that these countries play an important role in the establishment of scientific communication in mathematics education area and they serve as a bridge. Regarding the ranking of the countries according to the number of citations taken from the scientific studies that they have performed, it can be said that the authors from US, Turkey and Malaysia made the biggest citation bursts, respectively. From this result, it can be concluded that authors from USA have guided the works performed in the field and have made significant contributions to the development of the field. Another result is that authors from Chili are frequently referred by the recent works performed in the field. Based on the titles of the works cited by the studies included in the data set, the subjects mostly studied in the field were found to be elementary mathematics classroom, teacher education and achievement gap. The words that are mostly used in mathematics education research area were found to be mathematics, education, student and achievement. The ranking of the concepts according to their centrality degree revealed that mathematics, instruction, model and reform have the highest centrality values. A network analysis was performed for identifying frequently used words in the works published in the field of mathematics education based on the abstracts and keywords of the publications and according to the outcomes of the analysis mathematics, education, student and achievement were identified as most frequently used words.

Jiménez-Fanjul et al. (2013) performed bibliometric analysis of four journals, which mainly focused on mathematics education, scanned in SSCI between 1986-2011. The authors analyzed Journal for Research in Mathematics Education (JRME), Bolema-Mathematics Education Bulletin-Boletim de Educacao Matematica (BOLEMA), Educational Studies in Mathematics (ESM) and Revista Latinoamericana de Investigación en Matemática Educativa-Relime (RELIME) journals in four main dimensions, namely co-authorship patterns, diachronic production, publication language and universities' productivity of journals. They also analyzed the journals according to various sub-variables, including type of the work, year of the work, language of the work, number of works per university, total number of citations, collaborations, number of authors per article, number of articles per country. As a result of this analysis they found that the number of works starting with 56 in 1986 went to 276 in 2011. These works were respectively article (63.4%), book review (19.5%) and editorial material (8.7%); mostly used languages of publications were English (76.3%), Portuguese (18.6) and Spanish (3.9%). The most productive universities were respectively Michigan State University (1.5%), University of Georgia (1.3%) and Purdue University (1.3%). A total of 7805 citations were made to the works, average number of citation per work was 9.06; regarding the number of authors, the works with single author was 38.6%, whereas works with two authors were 35.9% and with three authors, 14.2%. Regarding the country

Table 6. Most used words in math/mathematics education research area.

Key words	Count	Keywords	Centrality
mathematics	1841	Mathematics	0.15
education	1732	Instruction	0.12
student	919	Model	0.12
achievement	893	Reform	0.12
mathematics education	714	Knowledge	0.10
science	657	Children	0.09
knowledge	619	Achievement	0.08
performance	566	School	0.08
school	546	Classroom	0.08
classroom	505	Student achievement	0.08
instruction	483	Education	0.07
teacher	429	Student	0.07
children	337	High school	0.07
professional development	308	Teacher	0.06
motivation	307	Curriculum	0.06
curriculum	295	Outcome	0.06
belief	295	Science	0.05
teacher education	290	Performance	0.05
technology	281	Motivation	0.05
Model	263	Attitude	0.05

contributions, they were ranked as US (32.4%), Brazil (15.8%) and Canada (5.9%).

Yalçın and Yayla (2016) addressed the researches made in Technological Pedagogical Content Knowledge (TPACK) area to reveal scientific communication of the researchers, determine the publications and authors that were active in the field and present comprehensive results in terms of author and publication. The study was conducted with a total of 543 publications addressing TPACK, in the form of book, article and review, obtained from Web of Science (WoS) and Scopus databases. Scientific communication pattern of TPACK field was addressed according to authors and works by using bibliometric method; and the authors and researches that came to the forefront were presented by visualizing via scientific mapping. By this means, comprehensive results were revealed using the publications and their authors.

Özsoy et al. (2017) categorized and analyzed 103 postgraduate and doctoral theses concerning mathematics education in classroom teaching, published in Turkey from 2005-2016. The categories were set as impact, book, teacher, student and curriculum according to the work areas of the theses. Postgraduate theses published in the defined years were analyzed according to the universities, academic titles of the advisors, years, research patterns and samples/workgroups. According to the results of the research, it was found that research patterns that have been mostly used in the theses were

scanning model, experimental design and qualitative design. Most preferred compositions in the researches were respectively 1-8th grade students, teachers and teacher candidates. It was found that works were concentrated around numbers and geometry.

Assefa and Rorissa (2013) analyzed the article's titles, keywords and abstracts concerning STEM education area in Web of Science and ERIC databases. The researchers used common word analysis method, figures and maps to look for clues about how STEM education will be shaped in the future, whether it will provide information that will illuminate the works of the educators who plan curriculums. For this purpose, they have scanned books, papers, articles and theses that included STEM education words in Web of Science and ERIC databases, published from 1901 to 2010. The researchers addressed various questions including, what are the main knowledge areas in STEM education and the relationships among them; how to use these results in developing curriculums; how to use these results in resource management and professional improvement activities.

The data set used in this study was formed based on the works concerning mathematics education, published in WoS database between 1980-2018. In this regard, this study can be described as the study having the most extensive data set compared to the works in which similar methods had been used; it aims to reveal the general

status of the field. This study is a pioneer for future works that will use similar methods. The collaboration pattern reached as a result of the study and collaboration structure belonging to outstanding works and authors should be considered as a guide that will form a starting point for future researches.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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