THEMATIC ANALYSIS OF ARTICLES ON FLIPPED LEARNING IN MATHEMATICS EDUCATION

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ABSTRACT

Researchers strive to create learning environments where they can apply technology and different teaching methods together. Flipped learning has been a popular approach in recent years because it offers opportunities for both online and offline learning. The present study aims to conduct a thematic analysis of articles on the use of the flipped learning model in mathematics courses. Meta-thematic analysis was adopted as the research method. In this context, for the study, 69 articles were selected from among those published between 2015 and June 2020. As a result, it was found that these studies on flipped learning in mathematics education were conducted primarily with undergraduate students, whereas insufficient numbers of studies have been conducted with primary school, middle school, and high school students and pre-service teachers. Researchers have often preferred the subject of analysis while implementing the model. Studies on the flipped learning model in mathematics have mainly aimed to examine academic performance and students' perceptions regarding the model. Although it can be argued that the flipped learning model positively affects the mathematical performance of students, studies have also reported that it had no effect on performance compared to traditional teaching methods. In addition, the present study provides comprehensive data on the positive and negative aspects of the use of the flipped learning model in mathematics courses. However, comprehensive, extensive, and long-term studies are needed to provide more clear results on the implementation of flipped learning in mathematics courses.

Keywords: Flipped learning approach, mathematics education, meta-thematic analysis.

INTRODUCTION

Flipped learning is a teaching model that represents a combination of the direct teaching method based on constructivist learning with behavioral principles, which are often thought to be incompatible (Bishop and Verleger, 2013). Jeong (2015) defines flipped learning as a mixed model in which both online and offline learning environments are used together. In this model, the traditional classroom environment is flipped by transferring learning content out of the classroom and activities are incorporated into the classroom environment (Hwang and Lai, 2017). The flipped learning model is defined as a pedagogical approach in which students are responsible for both pre- and post-course activities by Abeysekera and Dawson (2015), while Patterson, McBride, and Gieger (2018) define it as a type of active learning that focuses on the expectations of instructors and students in the classroom by ensuring pre-classroom preparation. Flipped classrooms offer a rich learning environment that enables independent learning as well as problem-solving, proper handling of materials, and development of high-level thinking (Murphy et al., 2016). They also play a role in the adoption of new learning technologies and tools (Pelletier et al., 2021).

In the literature, the terms "flipped learning," "inverted learning," and "flipped classroom" are used interchangeably (Muir, 2017). The term "flip" was adopted to refer to the combination of a Flexible environment (or a flexible learning space independent of time and space), Learning culture (an opportunity to deeply research topics in a student-centered and rich learning environment), Intentional content (considering what should be taught and what students should discover), and Professional educators (less conspicuous educators who are the main components in the realization of learning) (Flipped Learning Network [FLN], 2014). In this model, the instructor delivers recorded course videos to students before the class meets and conducts learning activities that ensure interaction and collaboration with students during classes (Mok, 2014). In other words, learning attained through videos and supporting materials provided before classes is supported with activities designed to enhance comprehension, practice, analysis, evaluation, and creation processes in the classroom (Cheng, Ritzhaupt, and Antonenko, 2019). Therefore, instructors take on new roles in the process of implementing the model. The instructor is a consultant who guides student groups in problem-solving and gives feedback and ideas during activities (Carter et al., 2018).

PROS AND CONS OF THE FLIPPED LEARNING MODEL

In the traditional classroom environment, the teacher is the source of information. However, as the flipped learning model entails a planned transition from a teacher-centric approach to a student-centered one, a number of changes occur in the learning culture. For example, topics are discussed more thoroughly and students can take part in information-building as they participate in interactive learning in an interactive classroom environment (Muir and Geiger, 2016). This model allows students to develop high-level thinking and active and collaborative learning skills (Long et al., 2017), and it ensures that they can engage in study and discussion with more activities (Zengin, 2017). Other perceived benefits of the model include exposing students to new materials outside the classroom, ensuring their preparedness for lessons, and empowering them as self-sufficient learners (Zack et al., 2015). It is further emphasized that the flipped learning model provides positive contributions such as diversified teaching, motivation, participation in the course, and increased student-teacher interaction (Muir and Geiger, 2016; Muir, 2017; Van-Sickle, 2015).

Flipped learning eliminates the comfort zone and offers many unknowns, and this creates changes in expectations (Wang, 2017). Therefore, in the process of implementing the model, both the teacher and the students may encounter certain difficulties. For example, the positive effects of the flipped learning model are not expected when students do not complete the activities prepared for them as planned outside of the classroom and the guidance of teachers (Zengin, 2017). Lo and Hew (2017a) argue that some students prefer to abandon the model when they do not fulfill the responsibility of learning or when they are challenged. Soliman (2016) notes that the group-work-centered nature of the model may be disliked by students who prefer individual study, while Heuett (2017) asserts that the model may not appeal to students who want to learn from the teacher and not through videos. In addition, it was reported that students resisted the model when they were not satisfied with the course materials (Lo and Hew, 2017a). Therefore, instructors must be very careful in preparing presentation content, videos, study notes, and activities (Zengin, 2017). However, some instructors perceive the material preparation process as an extra burden (Lo and Hew, 2017a) and this may cause them to have difficulty in adopting the model (Wang, 2017; Heuett, 2017). On the other hand, technological problems are one of the major disadvantages of this learning model. This is because some students may lack the technological infrastructure for watching course videos outside of the classroom (Kennedy et al., 2015; Soliman, 2016; Zengin, 2017). In addition, videos may not meet expectations if they do not have quality, consistent, clear, and concise contents (Mok, 2014).

REVIEW OF THE LITERATURE

Due to the significant trend toward flipped learning in recent years (Wang, 2017; Heuett, 2017), the model's effects have been investigated with content and thematic analysis studies. For example, Zainuddin et al. (2019) evaluated 48 experimental studies in different fields using content analysis. They determined that the model offers positive outcomes for students in terms of motivation, participation, social interaction, and self-managed learning skills. Another study using content analysis, conducted by Akcayir and Akcayir (2018), identified the advantages and disadvantages of the flipped learning model by examining 71 articles. As a result, it was established that the model positively affects learning performance, but there may be difficulties in practice in the event of inadequate preparation. O'Flaherty and Phillips (2015) evaluated 28 articles involving higher education applications of the flipped learning model using the scope study method. They found that the model positively influenced academic success and satisfaction, but there was no conclusive evidence that it developed 21st-century thinking skills. Karabulut-Ilgu et al. (2018) evaluated the model in terms of engineer training using 62 studies. Noting that the model had begun to gain popularity in engineering faculties, they described the benefits that it provided to students and trainers as promising. Tutuncu and Aksu (2018) examined 38 theses and articles on the flipped learning model in Turkey. They determined that the studies focused mostly on success, attitudes, motivation, and student perspectives. Lo and Hew (2017a) reviewed 15 experimental studies at the K-12 level in different fields. They found that the model had a positive impact on academic success compared to the traditional method, but it also introduced different challenges regarding practice, students, the classroom, and operational aspects. In another study on the impact of the flipped learning model on participation at the K-12 level, Bond (2020) examined 107 studies in different fields and established that the model affected behavioral, affective, and cognitive participation. In some studies, the meta-analysis method was used. For example, Karagol and Esen (2019) evaluated the impact of the flipped learning model on academic success using 55 theses and articles in different fields. They concluded that the model positively affected academic success in small groups, but this effect did not depend on the application process. Van Alten et al. (2019) investigated 114 studies and found that the model positively affected learning outcomes but had no effect on the learning environment or student satisfaction. Lo et al. (2017) evaluated 21 articles on mathematics education and determined that the flipped learning model had a significant impact compared to traditional classroom methods. Cheng et al. (2019) examined 55 studies in different fields and found that the flipped learning model had a significant impact on learning outcomes.

Aim of the Study

The present study focuses on articles exploring the use of the flipped learning model in mathematics courses. As the application area of the model is becoming increasingly wide and the model attracts growing attention (Mok, 2014), it is necessary to investigate how effective it is and what conclusions can be drawn from it, as well as evaluating the applications of the model in existing studies (Cheng et al., 2019). In addition, the findings to date need to be analyzed in order to obtain information about the positive and negative sides of the model, identify possible challenging situations, shed light on avenues for future research, and observe the developments (Karabulut-Ilgu et al., 2018). It was also thought that it would be helpful to provide a perspective for researchers who would like to evaluate the model from the point of view of mathematics education. In this context, the present study will contribute to the literature in several ways. This study aims to conduct a meta-thematic analysis of articles on the flipped learning model in mathematics courses. In accordance with this aim, answers to the following questions will be sought:

1. What are the publication years of the articles on the flipped learning model in mathematics courses and in which indexes were they published?
2. What are the study groups and mathematics subjects considered in the articles on the flipped learning model in mathematics courses?
3. What are the aims of the articles on the flipped learning model in mathematics courses?
4. What are the research methods, research durations, and sample sizes of the articles on the flipped learning model in mathematics courses?
5. What are the methods, techniques, and Internet access platforms used in the articles on the flipped learning model in mathematics?
6. What are the results of the articles on the flipped learning model in mathematics courses?
7. What are the suggestions of the articles on the flipped learning model in mathematics courses?

METHOD

The research was designed qualitatively. The data of the research were evaluated using meta-thematic analysis. Meta-thematic analysis is used to analyze, combine, and interpret each of the data in the scope of the study. The main goal here is to take the main concepts from and among the studies and present a synthesis instead of solely bringing together their findings (Batdi, 2019).

The thematic analysis process was carried out taking into account the steps defined by Batdi (2019). These stages are: (1) determining the research problem, (2) creating a conceptual framework for the problem, (3) determining the research questions, (4) determining the population and sample, (5) collecting data, (6) reviewing and examining the data, (7) coding data by categories, (8) creating definitions of data sources, (9) creating themes and testing hypotheses, and (10) reporting and interpretation.

Data Collection and Analysis

The research data were obtained from the Web of Science, British Education Index (BEI), Education Resources Information Center (ERIC), Google Scholar, Scopus, and TR-Index databases. The research sample of the study was limited to scholarly articles published in national and international journals between 2015 and 2020 (June). The publication language of the articles was usually English. In addition, Turkish articles from the TR-Index database were also reviewed, but only one article in Turkish was included in the study. Arksey and O'Malley (2005) suggest that broad keyword definition should be employed for search terms. In international articles, key terms such as "flipped" or "inverted teaching" and "flipped" or "inverted classroom" have been adopted (O'Flaherty and Phillips, 2015). A literature survey was conducted using the key concepts of "flipped," "flipped classroom," "flipped learning," and "inverted learning." The search using only these keywords produced many articles. Since the present study focuses on articles on the flipped learning model in mathematics courses, keywords describing the aim of the study or the mathematics domain and subjects such as "mathematics," "mathematics education," "geometry," "algebra," and "calculus" were also used. The selection criteria presented in Table 1 below were established for the articles that were planned to be included within the scope of the study.

Table 1. Selection criteria for articles

Criteria	Admissible	Non-admissible
Date	Between January 2015 and June 2020	Studies conducted outside this period
Language	English, Turkish	Articles not written in English or Turkish
Article type	Original article, peer-reviewed journals	Non-peer-reviewed journals, theses, and presentations
Accessibility	Full text available or accessible via libraries	Not accessible without permission
Subject area	Mathematics, mathematics education	Other fields
Application	Flipped classroom applied	Flipped classroom not applied

In this context, a preliminary evaluation was conducted at the beginning of the research process. In the preliminary evaluation, 235 articles published between 2015 and June 2020 were identified. The titles, abstracts, and keywords as well as the aims of the articles were examined to decide whether to include them within the scope of the study. For example, articles on healthcare were eliminated. Some articles were eliminated due to the lack of adequate explanation about the implementation of the flipped classroom model. Others were not included because they studied other fields in addition to mathematics or did not focus only on the field of mathematics. As a result, 69 articles were included within the scope of the study as they served the purpose of the study.

Data Analysis

Data were analyzed by thematic analysis. For such data analysis, studies on the same topic need to be critically synthesized and interpreted by creating themes and templates (matrix) (Calik and Sozbilir, 2014). Table 2 below provides detailed information about the thematic analysis matrix used for this study.

Table 2. Thematic analysis matrix used in the study

Features	Themes	Description
General	Year	The year of publication of the study
	Type	The index in which the study was included
Content	Study group	Participants of the study (e.g., students, teachers, pre-service teachers)
	Mathematics subjects	Mathematics subjects of the studies (e.g. analysis, numbers, geometry)
	Aim	Main purpose of the study
	Method	Research method used in the study (e.g., qualitative, quantitative, mixed)
	Duration	Duration of the study
	Sample size	Number of people participating in the study
	Method-technique	Methods and techniques used in the study (e.g., group work, discussion)
	Internet access platform	Internet access platforms used in the study (e.g. YouTube, Khan Academy)
	Results	Main results of the study
	Suggestions	Basic suggestions of the study

First of all, 69 articles in the scope of the study were subjected to document review with the help of the matrix used in Table 2. The articles were analyzed using content and descriptive analysis methods. Content analysis was used for general features and descriptive analysis for content features. Analytical coding was performed after the data were explicitly coded for descriptive analysis. For this coding process, the path indicated by Batdi (2019) was followed. Its stages include the following: (1) editing and analyzing the data; (2) re-examining and regenerating the data with different codes; (3) combining the codes and reducing them to a sufficient number of categories, and recording the data with the latest codes; (4) editing, summarizing, and creating descriptions; (5) creating large and small themes; and (6) performing the final analysis and interpreting the data.

To ensure the validity and reliability of the study, the coding process was conducted while obtaining the opinions of three different field experts. First of all, the individual opinions of the field experts were obtained in the creation of the initial encodings. A field expert regularly reported his or her opinions in the process of rebuilding the data with different codes. During the final coding phase, the reliability ratio was evaluated using the reliability coefficient of Miles and Huberman (1994). In this context, the reliability score was calculated as 83%. Agreement was sought through discussion in the event of disagreement among expert opinions.

FINDINGS

In this section, the findings obtained as a result of the evaluation of the 69 articles within the scope of the study are given.

a. Findings related to the publication year and indexing of the studies

Table 3 below provides information on the publication year of the articles in the scope of the study and the indexes in which they were published.

Table 3. Publication year and indexing of the articles

	Publication year of the article						n	%
	2015	2016	2017	2018	2019	2020		
SSCI	1	3	5	4	3	1	17	24.7
ESCI	2	3	4	—	3	4	16	23.2
ERIC	18	3	4	7	—	2	34	49.3
TR-Index	—	—	—	1	—	—	1	1.4
BEI	1	—		—	—	—	1	1.4
n (%)	22 (31.9)	9 (13.1)	13 (18.8)	12 (17.4)	6 (8.7)	7 (10.1)	69	100

As seen in Table 3, 34 (49.3%) articles on the flipped learning model in mathematics courses were published in journals indexed in ERIC, whereas 17 (24.7%) articles were indexed in SSCI and 16 (23.2%) articles in ESCI. Only 1 (1.4%) article was indexed in the TR-Index database. The highest number of articles was published in 2019 with 22 (31.9%) articles, while the smallest number of articles was published in 2015 with 6 (8.7%) articles. When the first half of 2020 was included in the study, the number of articles published in 2020 accounted for 10.1% of all articles covered in the study.

b. Findings related to the study groups and mathematics subjects of the studies

Figure 1 below provides information regarding the study groups of the articles in the scope of the study.

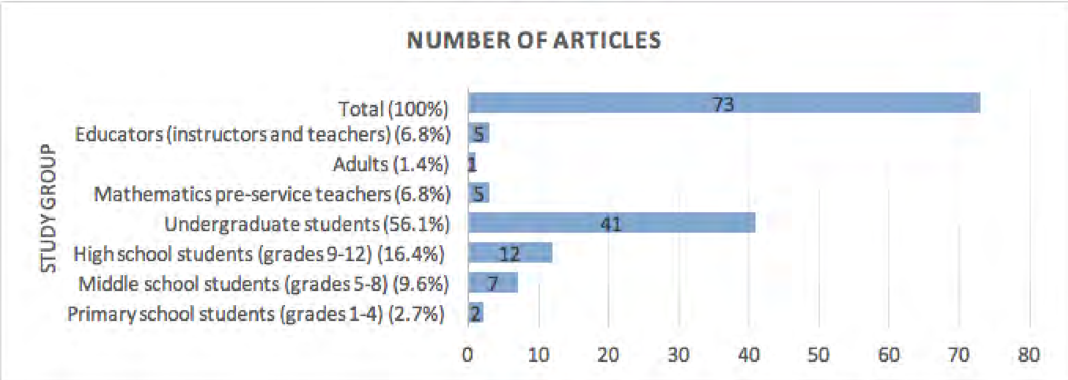

Figure 1. Study groups of the articles

As shown in Figure 1, 41 (56.1%) studies were conducted with undergraduate students while 12 (16.4%) studies were conducted with high school (9th-12th grade) students. The scarcity of studies carried out with primary and middle school students as well as with instructors and pre-service teachers was noted. In addition, the total number of articles reflected in Figure 1 is greater than the total number of studies within the scope of the present work, because three studies were conducted with both middle and high school students (e.g., Hung, Sun, and, Liu, 2019) and one study was conducted with both high school students and instructors (Muir and Geiger, 2016).

Figure 2 below provides information about the mathematics subjects of the studies within the scope of the present work.

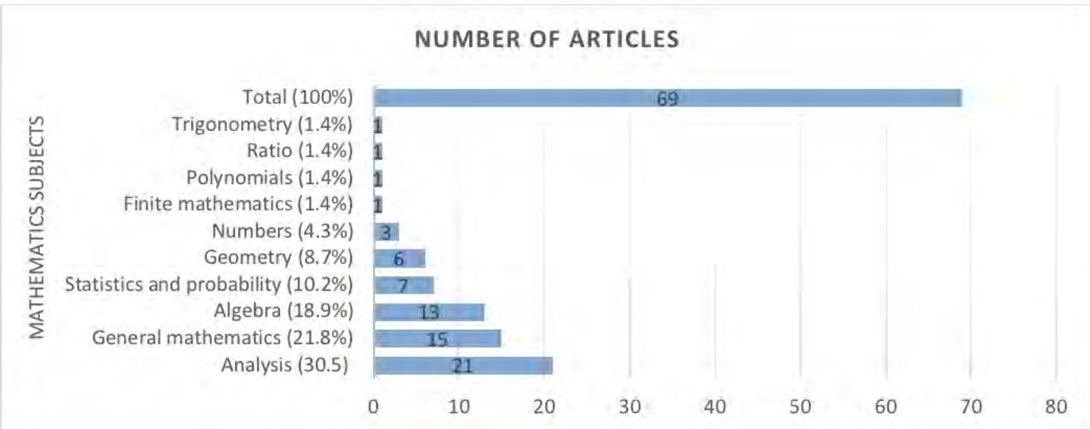

Figure 2. Mathematics subjects of the articles

As seen in Figure 2, in 21 (30.5%) articles, the flipped learning model application was carried out during a course in which the subject of analysis was taught, whereas general mathematics was the subject matter of 15 (21.8%) articles and algebra was that of 13 (18.9%) articles. Statistics and probability, numbers, finite mathematics, polynomials, trigonometry, and ratio were less preferred as subjects.

c. Findings related to the aims of the studies

The aims of the studies on the flipped classroom model in mathematics courses were gathered within four different themes. These themes were general, cognitive, and affective studies and studies aiming at evaluating the development of the model. Table 4 below provides information about the aims of the studies.

Table 4. Breakdown by study aims

Theme	Categories	f	%	Source
General	Academic performance	38	27.8	Wei et al. (2020)
	Participation	8	5.9	Kaya (2018)
	Motivation	6	4.5	Bhagat et al. (2016)
	Variables (e.g. gender, socioeconomic level)	4	2.9	Turra et al. (2019)
	Individual differences	2	1.4	Lo and Hew (2017b)
	Study habits	1	0.7	Sahin et al. (2015)
	Total	59	43.2	
Cognitive	Conceptual learning	4	2.9	Kirvan et al. (2015)
	Perception	3	2.2	Adams and Dove (2018)
	Learning strategies	2	1.4	Kennedy et al. (2015)
	Meta-cognition	1	0.7	Yong et al. (2015)
	Problem-solving	1	0.7	Anderson and Brennan (2015)
	Total	11	7.9	
Affective	Attitude	6	4.5	Guerrero et al. (2015)
	Self-efficacy	4	2.9	Krouss and Lesseig (2020)
	Interest	1	0.7	Chen et al. (2016)
	Anxiety	1	0.7	Dove and Dove (2017)
	Self-regulation	1	0.7	Lai and Hwang (2016)
	Self-evaluation	1	0.7	Lai and Hwang (2016)
	Target-setting	1	0.7	Lai and Hwang (2016)
	Engagement	1	0.7	Ichinose and Clinkenbeard (2016)
	Student needs	1	0.7	Muir (2020)
	Total	17	12.3	
Model Development	Student's point of view	20	14.7	Novak et al. (2017)
	Instructor's point of view	9	6.6	Naccarato and Karakok (2015)
	Teaching tips	7	5.2	Adams and Dove (2018)
	Positive and negative sides	4	2.9	Heuett (2017)
	Classroom design	4	2.9	Kraut (2015)
	Satisfaction	3	2.2	Nielsen et al. (2018)
	Effectiveness	2	1.4	Song and Kapur (2017)
	Course materials	1	0.7	Gouia and Gunn (2016)
	Total	50	36.6	
	General Total	137	100	

As seen in Table 4, 38 (27.8%) studies aimed to measure the impact of the flipped learning model on academic performance in mathematics courses. Akcayir and Akcayir (2018) point out that the flipped learning model's being a current subject plays a role in investigating its effects on academic performance. In 8 (5.9%) articles, the impact of the model on participation was investigated. Of all articles within the scope of the present work, 21.3% focused on the point of view of students and instructors, whereas 36.6% focused on the aims for developing the model. What should be noted regarding Table 4 is the scarcity of studies investigating the cognitive and affective dimensions of the flipped learning model in mathematics courses. The number of studies on topics such as perception, learning strategies, attitude, anxiety, and interest is quite small.

d. Findings related to research methods, research durations, and sample sizes of the studies

Figure 3 below provides information about the research methods of the studies.

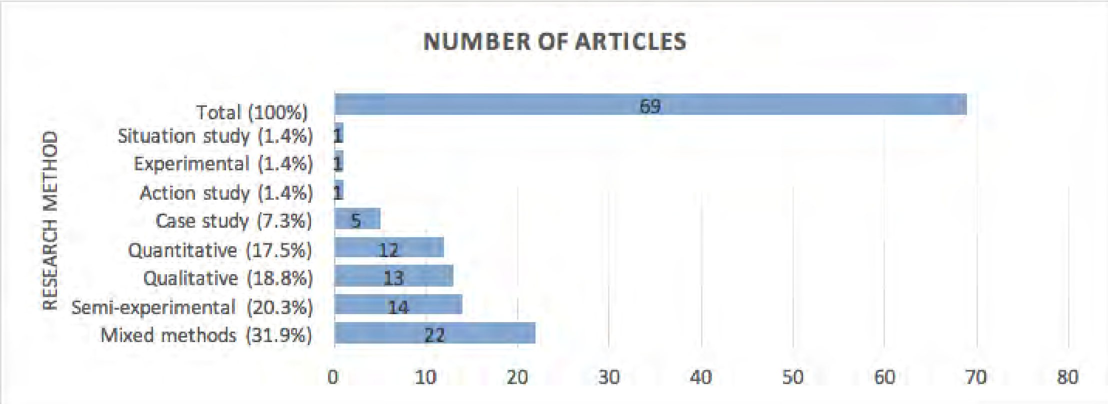

Figure 3. Research methods of the studies

As seen in Figure 3, 22 (31.9%) articles evaluated the flipped learning model in mathematics courses using a mixed method. Regarding other articles, 14 (20.3%) employed a semi-experimental research method, 13 (18.8%) a qualitative method, and 12 (17.5%) a quantitative method. Furthermore, the percentages of studies employing situation, action, experimental, and case study methods were lower than those of other studies.

Table 5 below provides information about the research durations and sample sizes of the studies.

Table 5. Research durations and sample sizes of the studies

Duration	f	%	Sample size (number of people)	f	%
1-5 weeks	7	10.4	Small scale (1-50)	39	56.5
6-11 weeks	7	10.4	Medium scale (51-100)	12	17.4
1 semester	34	50.8	Large scale (101 and above)	17	24.6
Longer than 1 semester	16	23.9	Not specified	1	1.5
Not specified	5	4.5	Total	69	100
Total	69	100			

As seen in Table 5, 34 (50.8%) studies implemented the flipped learning model in mathematics courses for one semester (e.g., Nielsen, Bean, and Larsen, 2018) and 16 (23.9%) studies for longer than one semester (e.g., Carter et al., 2018). Of all studies, 74.7% were long-term studies, while 7 (10.4%) studies each implemented the model for 1-5 weeks and 6-11 weeks. Of all studies, 20.8% were shorter than others and those were usually conducted with primary, middle, and high school students (e.g., Chen, Yang, and Hsiao, 2016; Kaya, 2018). Two studies (Hodgson et al., 2017; Naccarato and Karakok, 2015) were not included in the table above as they solely examined teachers' observations.

The sample sizes of the studies within the scope of the present research were coded as having small, large, and medium scales of samples. In terms of sample sizes, 39 (56.5%) articles presented small-scale (1-50), 17 (24.6%) articles large-scale (101 and above), and 12 (17.4%) articles medium-scale (51-100) studies.

e. Findings related to the methods and techniques used in the studies and Internet access platforms

Table 6 below provides information about the methods and techniques used in the reviewed studies.

Table 6. Methods and techniques used by the studies

Category	f	%	Source	Category	f	%	Source
Videos	52	18.4	Van-Sickle (2015)	Question-answer	13	4.6	Wei et al. (2020)
Group work	44	15.5	Capaldi (2015)	Individual study	11	3.9	Yong et al. (2015)
Discussion	34	12.0	Steen-Utheim and Foldnes (2018)	Cooperative	11	3.9	Ogden (2015)
Problem-solving	28	9.9	Lo and Hew (2020)	Online exams	9	3.2	Lo and Hew (2017b)
Homework	21	7.4	Cilli-Turner (2015)	Projects	6	2.1	Murphy et al. (2016)
Note-keeping	16	5.7	Palmer (2015)	Real-life situations	4	1.4	Lo et al. (2018)
Feedback	15	5.3	Novak et al. (2017)	Worksheets	3	1.1	Song and Kapur (2017)
Activities	15	5.3	Collins (2019)	Diaries	1	0.3	Lai and Hwang (2016)
				Total	283	100	

As seen in Table 6, during the implementation of the flipped learning model in mathematics courses, videos were used in 52 (18.4%) studies, group work in 44 (15.5%), discussion in 34 (12%), and problem-solving in 28 (9.9%). The other methods and techniques employed included homework, note-keeping, feedback, activities, question-answer, individual and collaborative work, online exams, projects, real-life situations, worksheets, and diaries.

Table 7 below provides information about the Internet platforms used in the studies.

Table 7. Internet access platforms used in the studies

Category	f	%	Source	Category	f	%	Source
YouTube	12	16.3	Heuett (2017)	Edpuzzle	1	1.3	Kaya (2018)
PowerPoint	9	12.2	Jeong (2015)	Okulistik	1	1.3	Kaya (2018)
Camtasia	6	8.5	Yong et al. (2015)	Maxima	1	1.3	Zengin (2017)
Moodle	5	6.8	Lo and Hew (2020)	Teacher Tube	1	1.3	Van-Sickle (2015)
Massive open online course	4	5.5	Chen et al. (2016)	Learning Management System	1	1.3	Amstelveen (2019)
Blackboard	4	5.5	Jensen-Vallin (2017)	Wiley Plus	1	1.3	Carter et al. (2018)
Khan Academy	4	5.5	Dove and Dove (2017)	SmoothDraw	1	1.3	Muir and Geiger (2016)
WeBWorK	3	4.1	Maciejewski (2016)	My StatLab	1	1.3	Cilli-Turner (2015)
Desire2Learn	3	4.1	Sun et al. (2018)	Sophia	1	1.3	Van-Sickle (2015)
GeoGebra	2	2.7	Weinhandl et al. (2020)	Dropbox	1	1.3	Bhagat et al. (2016)
Piazza	2	2.7	Ziegemeier and Topaz (2015)	Socrative	1	1.3	Song and Kapur (2017)
WebAssign	2	2.7	Patterson et al. (2018)	Google Hangouts	1	1.3	Murphy et al. (2016)
Google Docs	1	1.3	Murphy et al. (2016)	MyMathLab	1	1.3	Adams and Dove (2018)
Coursera	1	1.3	Salinas-Martinez and Quintero-Rodriguez (2018)	Maple Lab	1	1.3	Adams and Dove (2018)
Promethean ActivBoard	1	1.3	Clark (2015)	QQ Learning Platform	1	1.3	Wei et al. (2020)
				Total	74	100	

As seen in Table 7, 12 (16.3%) articles used YouTube as an Internet access platform, whereas 9 (12.2%) articles employed PowerPoint and 6 (8.5%) articles Camtasia. Other platforms used included Moodle, Khan Academy, and WeBWorK. It should be noted that instructors used their own videos instead of ready-made videos in 42 (60.8%) articles.

f. Findings related to the results of the studies

The results of the studies within the scope of this research were categorized according to three themes. These themes are the positive, negative, and ineffective results of the flipped learning model in mathematics courses. Table 8 provides information about the positive results of using the model in mathematics courses. The themes of positive results were determined as results that contributed positively to the use of the flipped learning model for students, instructors, the learning environment, and technology in mathematics courses.

Table 8. Positive results of the studies

Theme	Categories	f	%	Source
Student	Academic performance	29	9.9	Albalawi (2018)
	Learning	24	8.2	Wei et al. (2020)
	Peer communication	18	6.1	Lo and Hew (2017b)
	Positive overview of the model	17	5.8	Touchton (2015)
	Motivation	11	3.8	Chen et al. (2016)
	Participation	10	3.4	Kaya (2018)
	High-level thinking	8	2.7	Jensen-Vallin (2017)
	Learning responsibility	8	2.7	Lo et al. (2018)
	Study habits	8	2.7	Schroeder et al. (2015)
	Self-confidence	6	2	Ford (2015)
	Getting prepared before the lesson	6	2	Cilli-Turner (2015)
	Learning at your own pace	5	1.7	Gouia and Gunn (2016)
	Giving/getting help	5	1.7	Lo and Hew (2020)
	Attitude	4	1.4	Guerrero et al. (2015)
	Individual differences	4	1.4	Touchton (2015)
	Self-efficacy	3	1.1	Sun et al. (2018)
	Setting/achieving a goal	3	1.1	Lai and Hwang (2016)
	Decreased fear/anxiety	3	1.1	Ogden (2015)
	Satisfaction	2	0.7	Tse et al. (2019)
	Persistence of knowledge	2	0.7	Zengin (2017)
	Self-regulation	1	0.3	Lai and Hwang (2016)
	Access to information at will	1	0.3	Zack et al. (2015)
	Total	178	60.8	
Teacher	Teacher-student communication	13	4.4	Dove and Dove (2017)
	Recognition of the student	6	2	Anderson and Brennan (2015)
	Planning the classroom time	6	2	Dove and Dove (2017)
	Focus on deep and difficult topics	5	1.7	Lo and Hew (2017b)
	Preparing your own videos	3	1.1	Naccarato and Karakok (2015)
	Positive point of view on the model	3	1.1	Petrillo (2016)
	Feeling its presence in the classroom	1	0.3	Cronhjort et al. (2018)
	Intervening with students in time	1	0.3	Collins (2019)
	Total	36	12.9	

Learning Environment	Entertainment/engaging	8	2.7	Murphy et al. (2016)
	Different teaching methods	7	2.3	Fredriksen and Hadjerrouit (2020)
	Asking questions	7	2.3	Wei et al. (2020)
	Sharing ideas	5	1.7	Wasserman et al. (2017)
	Rich materials	4	1.4	Zengin (2017)
	Feedback	4	1.4	Naccarato and Karakok (2015)
	Doing math	4	1.4	Guerrero et al. (2015)
	Rich content	3	1.1	Clark (2015)
	Real-life applications	2	0.7	Yong et al. (2015)
	Unlike memorization	2	0.7	Combs et al. (2018)
	Flexible learning environment	2	0.7	Muir (2020)
	Student-centered	1	0.3	Clark (2015)
	Long-term	1	0.3	Hsiao et al. (2019)
	Effective teaching	1	0.3	Tse et al. (2019)
	Total	51	17.3	
Technology	Diversity of technology (e.g., online discussion and practice platforms, gamification, interactive e-books)	9	3.1	Fredriksen and Hadjerrouit (2020)
	Watching videos at will	5	1.7	Sahin et al. (2015)
	Videos	5	1.7	Steen-Utheim and Foldnes (2018)
	Repetition	4	1.4	Clark (2015)
	Watching videos at the desired speed	3	1.1	Johnston (2017)
	Total	26	9	
	General Total	293	100	

As seen in Table 8, 29 (9.9%) articles stated that the flipped learning model made positive contributions to the mathematical performance of students while 24 (8.2%) articles reported its positive effects on learning. The positive contributions of the model for students accounted for 61.5% of the total results. Positive contributions of the flipped learning model in mathematics courses for students included peer communication, motivation, participation, high-level thinking, study habits, self-confidence, persistence of knowledge, learning at one's own pace, learning responsibility, and reduced fear and anxiety about mathematics.

It was stressed in the articles that the flipped learning model in mathematics courses provides instructors with various opportunities including student-teacher communication, recognition of the student, correct usage of classroom time, ability to focus on profound and difficult topics, and timely intervention with students.

The flipped learning model in mathematics courses offers an interesting and entertaining learning environment, allowing the use of different methods and making it possible for students to ask more questions while providing rich materials and content. Technologically, it offers the possibility of using various technological tools and watching course videos at the desired time and speed with the option of re-viewing them.

Table 9 below provides information about the negative consequences of the flipped learning model in mathematics courses.

Table 9. Negative results of the studies

Categories	f	%	Source
Passively watching/not watching videos	13	18.3	Adams and Dove (2018)
Difficulty in adapting to the model	10	14.1	Chen et al. (2016)
Workload	10	14.1	Lo et al. (2018)
Time-consuming	8	11.2	Anderson and Brennan (2015)

Inability to ask questions while watching videos	4	5.7	Zack et al. (2015)
Technical problems	4	5.7	Lo et al. (2018)
Learning topics from the instructor	4	5.7	Jeong (2015)
Limited resources	2	2.8	Anderson and Brennan (2015)
Failure to ensure consistent participation	2	2.8	Steen-Utheim and Foldnes (2018)
Having fewer lessons	2	2.8	Ziegemeier and Topaz (2015)
Difficulty in self-learning	2	2.8	Zack et al. (2015)
Technological incompetence	1	1.4	Zengin (2017)
Poor quality of videos	1	1.4	Wasserman et al. (2017)
Costs	1	1.4	Touchton (2015)
Anxiety	1	1.4	Heuett (2017)
Applying it for the whole semester	1	1.4	Guerrero et al. (2015)
Superfluity of the school	1	1.4	Heuett (2017)
Seeing the teacher's function as insufficient	1	1.4	Van-Sickle (2015)
Difficulty in following the lesson	1	1.4	Yong et al. (2015)
Lack of motivation	1	1.4	Tse et al. (2019)
Finding the model insufficient	1	1.4	Lesseig and Krouss (2017)
Total	71	100	

As seen in Table 9, 13 (18.3%) articles reported students coming to class without watching videos or attending the course as a passive audience as factors disrupting the flipped learning model in mathematics courses. In 10 (14.1%) articles, it was emphasized that the model introduced a burdensome workload to students and teachers and they had difficulty adapting to the model. The fact that the flipped learning model in mathematics courses takes times to apply, may have technical problems, entails fewer lessons, involves difficulty in self-learning, might lead to the perception of the teacher's function as insufficient, is applied for the entire semester, leaves students unable to ask questions while watching videos, and impacts the desire to learn topics from the instructor were determined as negative results.

In addition to the studies reporting positive or negative consequences of the flipped learning model in mathematics courses, there are also studies comparing the model with traditional methods and reporting the ineffectiveness of the model. Although the percentage of these results is relatively small compared to other results, there are points to consider. Table 10 below provides information about the results on the ineffectiveness of the model.

Table 10. Results for the ineffectiveness of the model

Categories	f	%	Source
Academic performance	11	48	Yong et al. (2015)
Individual differences	2	9	Bhagat et al. (2016)
Understanding the course contents	1	4.3	Guerrero et al. (2015)
Self-efficacy	1	4.3	Krouss and Lesseig (2020)
Learning strategies	1	4.3	Kennedy et al. (2015)
Meta-cognitive and affective gains	1	4.3	Yong et al. (2015)
No clear conclusion that it increases learning	1	4.3	Guerrero et al. (2015)
Belief in learning mathematics	1	4.3	Adams and Dove (2018)
Ability to calculate	1	4.3	Anderson and Brennan (2015)
Gender attitudes	1	4.3	Turra et al. (2019)
Short-term learning	1	4.3	Hsiao et al. (2019)
Video preferences	1	4.3	Gouia and Gunn (2016)
Total	23	100	

As seen in Table 10, 11 (48%) articles concluded that the flipped learning model did not make a significant difference in students' academic performances in mathematics education. In addition, others reported no effect of the model on understanding the course contents, self-efficacy, learning strategies, meta-cognitive gains, increasing learning, belief, ability to calculate, attitude, short-term learning, or video preferences.

g. Findings related to the suggestions of the studies

The suggestions of the studies for the flipped learning model in mathematics courses are divided among themes of research topics, technical infrastructure, students, instructors, and teaching tips. Table 11 below provides information about the suggestions of the studies.

Table 11. Suggestions of the studies

Theme	Categories	f	%	Source
Research Topics	Different variables (e.g., causes of failure, attitude, effectiveness of the model, STEM, gamification, classroom structure, economic level, individual differences, impact of different types of training)	15	12.7	Bhagat et al. (2016)
	Comprehensive and experimental research	10	8.5	Lo and Hew (2017b)
	Large-scale	9	7.6	Kaya (2018)
	Long-term	9	7.6	Dove and Dove (2017)
	Different mathematics subjects	4	3.4	Hung et al. (2019)
	Classroom design	2	1.7	Clark (2015)
	Primary and middle school students	1	0.9	Muir (2020)
	The point at which technology will lose its effect	1	0.9	Clark (2015)
	Total	51	43.3	
Technical	Technical infrastructure	7	5.9	Touchton (2015)
	Rich content (e.g., videos, games)	5	4.2	Kirvan et al. (2015)
	Video time	3	2.5	Carney et al. (2015)
	Video design	2	1.7	Carter et al. (2018)
	Total	17	14.3	
Instructor	Time	3	2.5	Chen et al. (2016)
	Making your own videos	3	2.5	Muir and Geiger (2016)
	Expressing expectations clearly	2	1.7	Weinhandl et al. (2020)
	Guidance for students	1	0.9	Jeong (2015)
	In-service training	1	0.9	Albalawi (2018)
	Making efforts	1	0.9	Chen et al. (2016)
	Total	11	9.4	
Student	Coming to class unprepared	4	3.4	Lo et al. (2018)
	Consistent participation	3	2.5	Adams and Dove (2018)
	Note-keeping	1	0.9	Palmer (2015)
	Study habit	1	0.9	Jeong (2015)
	Total	9	7.7	
Teaching Tips	Well-organized classroom environment	8	6.8	Chen et al. (2016)
	Assessment tools (e.g., absenteeism, video watching, online discussion)	7	5.9	Lo and Hew (2017b)
	Feedback	5	4.2	Jeong (2015)
	Individual differences	3	2.5	Cronhjort et al. (2018)
	Not being suitable for every student	3	2.5	Petrillo (2016)
	Group work	3	2.5	Palmer (2015)
	Multiple instructors	1	0.9	Ogden (2015)
	Total	30	25.3	
	General Total	118	100	

As seen in Table 11, 15 (12.7%) articles suggested that different variables should be used, 10 (8.5%) articles suggested that comprehensive and experimental studies should be conducted, and 9 (7.6%) articles suggested that large-scale and long-term studies should be carried out. It was stated that instructors who want to use the flipped learning model in mathematics courses should be given time. It was also suggested that training will be more effective if instructors make their own videos, explain their expectations at the beginning of the application, and act as guides throughout the process. Students were advised to prepare for the lesson in advance and ensure consistent participation in order to benefit from the model efficiently. At the same time, instructional tips for those who would apply the model included preparing technical infrastructure with rich content, taking care of video time and design, ensuring well-organized courses and diversity in evaluation tools, providing feedback, and paying attention to individual differences.

DISCUSSION, CONCLUSIONS, AND SUGGESTIONS

Within the scope of the present study, 69 different articles on the flipped model in mathematics education were examined and evaluated. It was found that most of the articles were published in 2015 and in journals indexed by ERIC. The scarcity of relevant articles included in the TR-Index database was noted.

More than half of the studies on the flipped learning model in mathematics courses were conducted with undergraduate students. Although there were some studies conducted with primary school, middle school, and high school students applying the flipped learning model in mathematics courses, it can be said that their numbers were inadequate. In the studies conducted, it was argued that the flipped learning model gains momentum at K-12 and undergraduate levels (Cheng et al., 2019; Bergmann and Sams, 2012), but the scarcity of studies conducted at the K-12 level was also highlighted (Lo and Hew, 2017a; Akcayir and Akcayir, 2018). This, in turn, leads to limited knowledge of the difficulties experienced in the process of implementing the model in pre-undergraduate age groups (Lo and Hew, 2017a). Another observation made in the present study was the scarcity of studies conducted with mathematics pre-service teachers and instructors. It is necessary to create learning environments for mathematics pre-service teachers in order to enable them to gain experience in applying this method when they start to work as instructors in the future. In addition, carrying out studies examining the perspectives of mathematics instructors is important to learn how to apply the model in mathematics classes and how it can be developed.

Researchers primarily preferred the subject of analysis to implement the flipped learning model. It is believed that this was because undergraduate students were chosen for studies and analysis is usually one of the compulsory subjects taught in mathematics education in the first years of university.

The research methods employed in the studies on the flipped learning model in mathematics courses were diverse. These studies mostly adopted the mixed method (e.g., Guerrero et al., 2015; Muir, 2020; Murphy et al., 2016; Schroeder et al., 2015) or the semi-experimental method (e.g., Kirvan et al., 2015; Lo et al., 2018; Touchton, 2015), while the number of studies choosing the qualitative method (e.g., Jeong, 2015; Larsen, 2015; Ogden, 2015) or the quantitative method (e.g., Anderson and Brennan, 2015; Patterson et al., 2018; Sun et al., 2018) was also noteworthy. To study the effectiveness of the flipped learning model, Bishop and Verleger (2013) recommend experimental and semi-experimental methods, while Karabulut-Ilgu et al. (2018) suggest that qualitative and mixed methods should be used to understand how the model supports learning.

It was found that the majority of the studies on the flipped learning model in mathematics courses took place for an entire semester or longer. However, Cheng et al. (2019) indicate that long-term studies have a smaller impact than short-term ones. They suggest undergraduate students for long-term studies and primary, middle, and high school students for short-term studies. Lo and Hew (2017a) state that long-term studies are needed at the K-12 level in order to be able to evaluate the model. When we look at the sample sizes of the studies within the scope of the present work, it is noted that more studies have been carried out with groups of less than 50 people. Karagol and Esen (2019) recommend groups of 30 or fewer for the flipped classroom model.

Active learning and group work are the main themes of the flipped learning model (Novak et al., 2017). Overall, the flipped learning provides opportunities to use many teaching methods and techniques. In this regard, the model allows the use of different methods rather than adopting a specific method and technique. Most of the studies examined different combined methods such as videos, group work, discussion, problem-solving, homework, note-taking, feedback, activities, question-answer, and individual and collaborative work. Similarly, Akcayir and Akcayir (2018) indicate that there are many methods that can be used both inside and outside the classroom, and most researchers prefer to use multiple methods together. Thus, the development of 21st-century thinking skills and students' technology and information literacy can be supported (Zainuddin et al., 2019).

The studies on the flipped classroom model in mathematics courses generally aimed at examining academic performance and student perspectives. Akcayir and Akcayir (2018) state that academic performance is the overall objective of studies on the flipped learning model. Guerrero et al. (2015) note that although the studies on students' learning and academic performance in mathematics courses are limited, they are promising. Accordingly, many articles focused on the comparison between academic achievements in flipped classrooms and traditional classrooms (Karagol and Esen, 2019; O'Flaherty and Phillips, 2015). However, there is little consensus on which method is more effective (Karabulut-Ilgu et al., 2018; Cheng et al., 2019). This is due to the fact that there are few extensive studies on the model (DeLozier and Rhodes, 2017). Other variables besides academic performance are important for mathematics courses. Therefore, studies examining the effects of the flipped learning model in mathematics courses on factors such as participation, motivation, cognitive skills, and attitudes are needed. At the same time, the perspective of students and instructors that will provide information about the positive and negative aspects as well as aspects that need to be improved in the process of implementing the model can be examined. The scarcity of different studies on the impact of the model on mathematics education such as classroom design and material usage to provide instructional tips is noteworthy.

The vast majority of the studies evaluating academic performance came to the conclusion that the model positively influenced students' mathematical achievements. On the other hand, there are studies that argued that although there were no negative results for academic performance, the model did not have any positive impact on academic success. As an interesting finding, Bond (2020) reports that flipped learning positively affects attitudes, motivation, interest, self-efficacy, and attendance even if it does not improve students' academic performance. Experimental studies are needed to say that the flipped learning model is more effective compared to the traditional method (O'Flaherty and Phillips, 2015; Akcayir and Akcayir, 2018). The reported positive results of the studies within the scope of the present review are greater in comparison with negative and ineffective results. These positive aspects may be promising for mathematics education. Akcayir and Akcayir (2018) report an encouraging number of advantages (e.g., motivation, attitude) of the model in the studies conducted, whereas Karabulut-Ilgu et al. (2018) emphasize that the model is more effective than the traditional method. O'Flaherty and Phillips (2015) state that the results of studies focusing on the perspectives of students on the model are generally positive and few report negative views.

The flipped learning model offers a broad conceptual teaching framework that gives responsibility to students for learning outside the classroom (Phillips and Trainor, 2014). This model has promising as well as challenging aspects (Chen, Wang, and Chen, 2014). When students do not fulfill their responsibilities sufficiently, certain difficulties occur in the implementation of the model. The majority of the negative results of the studies within the scope of the present review occurred when students did not fulfill those responsibilities. Zainuddin et al. (2019) found that instructors faced the biggest challenge when students failed to watch videos, whereas Lo et al. (2017) reported that problems arose when students were not familiar with the model and when instructors perceived the model as adding to their workload. Many students find it hard to change their passive learning habits inherited from traditional classroom environments (Chen et al., 2014). Examining the reflections of the flipped learning model in mathematics courses, the present study identified watching videos passively, resistance to the model, time, and workload as the most common challenges. When out-of-class learning is not achieved, students have difficulty understanding the different forms of representation and different situations of concepts even if they understand the general framework of mathematical concepts (Zengin, 2017). In addition, there may be other challenges for mathematics courses, such as students wanting to learn the subject from the instructor, difficulty learning on their own, technical problems, and seeing the teacher's function as inadequate. However, Lo and Hew (2017a) argue that negative comments from students are important in terms of contributing to the development of the model. To overcome these adverse situations, activities that enable student and instructor engagement to enhance gamification, digital transformation, and creativity are proposed (Murillo-Zamorano et al., 2019).

The suggestions of the studies on the flipped learning model in mathematics courses include instructors preparing their own videos for trainings. Although online platforms such as YouTube and Khan Academy provide educational videos, videos on every topic are not available. Therefore, this suggestion may mean extra time and workload for instructors (Chen, 2016), but the impact will be greater.

The findings of this study will provide guidance for researchers who want to use the flipped classroom model in mathematics education. In conclusion, there are both positive and negative aspects of the flipped classroom model in mathematics lessons. Comprehensive, large, and long-term studies are needed to interpret the effects of the flipped classroom model for mathematics education from different perspectives.

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