



INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES



Trends of the Implementation of Hybrid Teaching and Learning in Mathematics Education: A Systematic Literature Review

Razzatul Iza Zurita Rasalli, Mohd Effendi @ Ewan Mohd Matore

To Link this Article: <http://dx.doi.org/10.6007/IJARBSS/v13-i2/16220> DOI:10.6007/IJARBSS/v13-i2/16220

Received: 04 December 2022, **Revised:** 06 January 2023, **Accepted:** 20 January 2023

Published Online: 09 February 2023

In-Text Citation: (Rasalli & Matore, 2023)

To Cite this Article: Rasalli, R. I. Z., & Matore, M. E. @ E. M. (2023). Trends of the Implementation of Hybrid Teaching and Learning in Mathematics Education: A Systematic Literature Review. *International Journal of Academic Research in Business and Social Sciences*, 13(2), 256 – 273.

Copyright: © 2023 The Author(s)

Published by Human Resource Management Academic Research Society (www.hrmars.com)

This article is published under the Creative Commons Attribution (CC BY 4.0) license. Anyone may reproduce, distribute, translate and create derivative works of this article (for both commercial and non-commercial purposes), subject to full attribution to the original publication and authors. The full terms of this license may be seen at: <http://creativecommons.org/licenses/by/4.0/legalcode>

Vol. 13, No. 2, 2023, Pg. 256 – 273

<http://hrmars.com/index.php/pages/detail/IJARBSS>

JOURNAL HOMEPAGE

Full Terms & Conditions of access and use can be found at
<http://hrmars.com/index.php/pages/detail/publication-ethics>



INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES



www.hrmars.com

ISSN: 2222-6990

Trends of the Implementation of Hybrid Teaching and Learning in Mathematics Education: A Systematic Literature Review

Razzatul Iza Zurita Rasalli, Mohd Effendi @ Ewan Mohd Matore

Faculty of Education, National University of Malaysia, Selangor, Malaysia

Email: p112390@siswa.ukm.edu.my, effendi@ukm.edu.my

Abstract

Since the Covid-19 pandemic, the term hybrid is increasingly used as one of the efforts to solve problems related to constraints due to standard operating procedures. Unfortunately, the hybrid concept in teaching and learning is not discussed much there is a need to know the research trends to improve the teaching and learning process, especially in Mathematics education. Data were collected using a systematic literature review (SLR) method based on keywords in the leading data databases Scopus and WOS. A total of 41 final articles with full access within a period of five years (2018-2022) have been identified based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) involving four phases, namely identification, then screening, eligibility review and inclusion inspection. Trend findings show research that has a positive impact on hybrid teaching and learning based on the year of publication, research approach, country of the author, and purpose of the study. The implications of this study can improve the country's educational aspirations to improve the education system in line with industrial revolution 4.0 and provide valuable contributions to scholars or researchers with a critical evaluation of existing research. Further studies can be carried out through more in-depth studies and further developed by future researchers to determine the effectiveness of the implementation of hybrid teaching and learning that can be linked to Mathematics education.

Keywords: Teaching and Learning, Hybrid, Mathematics Education, Systematic Literature Review

Introduction

In the era of industry 4.0, the use of technology in education is indeed inseparable, and the effectiveness of using information technology is often the choice of research researchers. The integration between information technology (IT) and teaching interfaces is known as hybrid teaching and learning. This learning is an attempt to combine the best elements of face-to-face teaching and the best aspects of distance education. The effects of this hybrid teaching and learning approaches have been in action studies and are more effective than traditional methods.

The term hybrid used refers to the combination of information technology and face-to-face teaching at the same time or at different times. Therefore, there are several students who

study in class, while several others will follow learning at home. This is implemented in rotation with the number of students in a class being divided into two groups and following the learning based on the schedule given by the educational institution whether at the school or higher education level.

Face-to-face and online learning have their own strengths and weaknesses. Thus, this hybrid teaching and learning is one of the alternative solution methods that can reduce the weaknesses of each approach. Among the advantages of this hybrid method approach is more flexible learning. Through this approach, educators will be more flexible in teaching mode, as well as students in achieving their learning materials. The merger of teaching and learning also has pros and cons for students and educators. The development of hybrid teaching and learning abroad is one of the innovative learning models to build and develop high mathematical thinking and give students the opportunity to represent and abstract mathematical concepts understood in learning (Aristika et al., 2021). While the development of hybrid teaching and learning in Mathematics in Malaysia, it is seen as a combination of traditional and online approaches opening a new chapter for students and teachers in facing the challenges of technology and communication skills of the 21st century.

However, the development of previous studies conducted shows that there is not much discussion of hybrid teaching and learning in a systematic way that is directed to the context of mathematics education. This systematic discussion is important to explore new issues of hybrid teaching and learning in Mathematics that will be studied in the future, especially in Malaysia. Thus, the objective of this literature review is to identify the trend of implementing hybrid teaching and learning in mathematics education based on the year of publication, the research approach, the country of the author, and the purpose of the study.

The reasons for hybrid teaching and learning in mathematics education need to be investigated, including how it can nurture students and teachers in the practical use of information and communication technology. In fact, this approach can improve the shortcomings found in traditional and online teaching. We need to know about the growth of hybrid teaching and learning in mathematics by reviewing the knowledge development because we are opening a new chapter in the world of education so that the students who want to be born fulfil the national mission and aspiration and that the success in achieving the desired learning outcomes through this approach becomes the best. The Ministry of Education really needs this information to prepare some interventions and so that the human capital in mathematics education that is taught not only achieves learning objectives but can also cultivate 21st century skills. The dropout of knowledge in the field of technology according to the times will slow down the National Mission to produce human capital of global standard. Various skills need to be applied through education, and providing quality education is the most effective strategy for shaping the excellence of students and teachers. This study provides an interesting and exciting opportunity to advance our knowledge of hybrid teaching and learning in mathematics based on the transformation in mathematics education that needs to be done so that the wishes and mission of the state can be achieved. The hybrid approach is seen as giving students the opportunity to develop their potential. Therefore, this study makes a major contribution to research on the body of knowledge in mathematics by expanding the research systematic review and focusing on hybrid teaching and learning in

mathematics education to successfully motivate students in this direction while fostering a lifelong learning culture.

This project provided an important opportunity to advance the understanding of hybrid teaching and learning in mathematics according to specific trends. The study offers some important insights into focus group of students, teachers, and administrators by giving sort of awareness on how to empower the student's development strength on hybrid teaching and learning in Mathematics. This review has a high need in pedagogical theoretical development for the reason that systematic literature review can arrange the trends of hybrid teaching and learning effectively. This will help others to implementing hybrid learning and teaching where it is an effective alternative and provides opportunities for the new generation with better learning and communication activities regardless of time and place factors. Using this literature review allows us to know the effectiveness, feasibility, needs, obstacles, and problems encountered in implementing hybrid learning and teaching.

Research Methodology

Literature Search Procedure

The systematic literature highlight study method based on PRISMA 2020 aims to complete reporting to find relevant papers, there are four systematic techniques used in this phase which are identification, screening, qualification, and selection. This study has fully synthesized the research trend using this method, resulting in an organized and transparent systematic literature review.

Identification

The literature search strategy begins with the objective of the study. Because this study focuses on hybrid teaching and learning instruments, the keywords determined are based on the title of the study using English. The main databases used in this literature search are Scopus and Web of Science (WOS). These two databases are the most comprehensive sources of publications and impact indicators and facilitate literature searches because these databases are a systematic and comprehensive collection of literature data. Scopus was used as an article search because it is listed as the world's most extensive coverage database in the field of scientific journals, guaranteed in search and focused context (Jeroen et al., 2020). At an early stage in the systematic review covering the identification process as reported in the PRISMA 2020 guidelines. Four (4) important terms emerged from the research question: factors, effects, online teaching, hybrid learning, and mathematics education. To supplement the search for this term, the researcher has searched for synonyms by using synonym dictionaries such as thesaurus.com. Search functions such as field code functions, phrase searches, wildcards, truncation, and Boolean operators were used to process these term combinations (Table 1). Based on the selected database, a total of 173 possible articles were identified, 120 from the Scopus database and 53 from the Web of Science database.

Table 1

Keywords search string used for the systematic review process.

Database	Keywords
Scopus	TITLE-ABS-KEY(("effect*" OR "reaction*" OR "outcome*" OR "factor*" OR "element*" OR "influence") AND ("online teaching*" OR "hybrid learning") AND ("mathematics" OR "mathematic education"))
Web of Science	TS= (("effect*" OR "reaction*" OR "outcome*" OR "factor*" OR "element*" OR "influence") AND ("online teaching*" OR "hybrid learning") AND ("mathematics" OR "mathematic education"))

Screening

To identify the appropriate articles, some criteria are listed in Table 2. The first step at this stage is the exclusion of journals (literature systematics), book series, books, chapters in books, and proceedings papers. Then, the published articles are screened by the year starting from 2018 to 2022 considering the concept of 'research field maturity' as emphasized by (Kraus et al., 2020). There are several criteria that have been set by the writer, namely: (i) articles published from 2018 to 2022; (ii) articles from journals only; (iii) articles related to the field of hybrid teaching and learning studies; and (iv) complete articles (full text).

This study has decided to review research papers written in English only. This process excluded 90 articles because they did not meet the inclusion criteria. As a result, 83 articles were found suitable for further screening, and after the screening, 25 duplicate articles were removed. Based on the inclusion and exclusion criteria, there were 58 articles remaining for evaluation in the next stage.

Table 2

Determination of instrument screening criteria.

Criteria	Qualifications	Exceptions
Document type	Journal (Study article)	Journals (systematic reviews), book series, titles in books and proceedings papers.
Language	English	Not English
Year of publication	Between 2018 and 2022	Before 2018

Eligibility

This third stage is the qualification process after completing the screening process. To ensure that the rest of the article meets the desired criteria, the author checks each article manually and this step is carried out based on reading the article title, abstract, or the entire article. Based on this process, a total of 17 articles were released because they did not focus on the search for hybrid teaching and learning in mathematics education and there were also articles that could not be downloaded by the researcher. Finally, a total of 41 high-potential articles were used as data for this systematic literature review.

Included

Based on the screened results, the number of articles obtained from Scopus is 10 articles while WOS is 31 articles. Referring to the inclusion and exclusion criteria, the last 41 articles were

selected for a systematic literature review, where brief statistics on the articles obtained and reported are as follows in Table 3:

Table 3

Statistics obtained through study screening.

Database	Frequency	Eligibility articles	Included articles
Scopus	120	17	10
WOS	53	41	31

The articles used in this systematic review have the theme of implementing hybrid teaching and learning in mathematics education. Therefore, the articles obtained after the screening process, qualifications, and selection, are reviewed to meet the objectives of the study. The following are studies identified based on the PRISMA 2020 systematic study diagram.

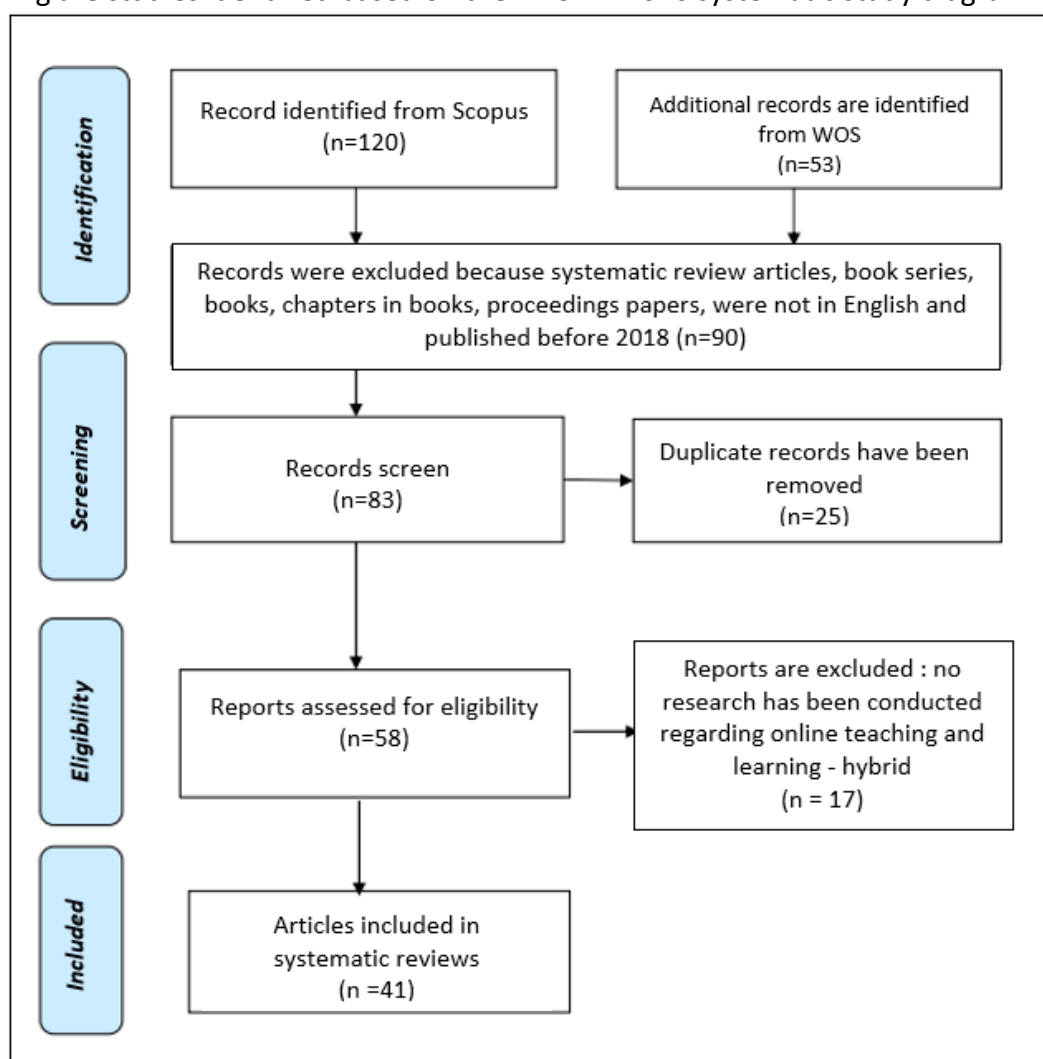


Figure 1. The flow diagram for the database search of publications for systematic reviews.

Data Analysis

The articles have been selected and analyzed using Microsoft Excel 365 to extract the year of publication, research approach, country of the author, and the purpose of the study as in Table 4.

Table 4
Summary of findings.

Author (year) and Title of Articles	Research approach	Country	Purpose of the study
Aristika et al (2021) <i>The effectiveness of hybrid learning in improving of teacher-student relationship in terms of learning motivation</i>	QN	Indonesia	Testing the effectiveness of hybrid learning in improving students' progress in mathematical theory.
Ashraf et al (2021) <i>A Systematic Review of Systematic Reviews on Blended Learning: Trends, Gaps and Future Directions</i>	QL	China	Identify blended learning trends, gaps, and future directions among students to learn actively and improve their learning outcomes.
Bakar & Ismail (2020) <i>Metacognitive online discussion for online teaching: A conceptual and impact on students engagement and mastery during coronavirus outbreaks</i>	QL	Malaysia	Develop an online mathematics instructional model that integrates metacognitive rule learning strategies with common active learning criteria and motivating online instructional design.
Batra et al (2021) <i>Traditional vs e-teaching learning due to covid-19: A case study for mathematics course</i>	QL	India	Analyze the impact of conventional teaching methods on student learning achievement.
Bouck & Long (2021) <i>Online Delivery of a Manipulative-Based Intervention Package for Finding Equivalent Fractions</i>	QL	United States of America	Implement effective technology platform interventions that include a variety of age and skill levels and math concepts.
Brunetto et al (2022) <i>Teaching as a system: COVID-19 as a lens into teacher change</i>	QL	Italy	Analyzing how the practices, knowledge, and beliefs of university mathematics professors interrelate and change during the pandemic.
Cao et al (2021) <i>Post-pandemic reflections: lessons from Chinese mathematics teachers about online mathematics instruction</i>	QN	China	Examines teachers' perceptions in China of the impact of online instruction on mathematics learning and examines the challenges they face as the country transitions to online instruction during the COVID-19 pandemic.

Author (year) and Title of Articles	Research approach	Country	Purpose of the study
Cavanaugh et al. (2022) <i>Variation in Student Perceptions of Higher Education Course Quality and Difficulty as a Result of Widespread Implementation of Online Education During the COVID-19 Pandemic</i>	QN	United States of America	Studying students' perceptions more specifically see the Covid-19 pandemic changing the difficulty and quality of learning.
Chen & Huang (2018) <i>Empirical Study on the Factors Influencing the Web-based Teaching Effect</i>	QN	China	Studying the factors affecting online teaching with the method of integrated technology acceptance model and social cognitive theory from a cognitive point of view.
Church et a (2021) <i>Useful Teaching Strategies in STEMM (Science, Technology, Engineering, Mathematics, and Medicine) Education during the COVID-19 Pandemic</i>	QL	United States of America	Studying the appropriate teaching methods used for STEMM courses, flexible class sizes where educational capabilities change from classroom to hybrid or online teaching methods.
DeCoito & Estaiteyeh (2022) <i>Transitioning to Online Teaching During the COVID-19 Pandemic: an Exploration of STEM Teachers' Views, Successes, and Challenges</i>	MM	Canada	Studying the transition of online teaching and learning methods for STEM teachers.
Durandt et al (2022) <i>Teaching and learning first-year engineering mathematics at a distance: A critical view over two consecutive years</i>	QN	South Africa	Identifying critical elements in the new classroom environment of online teaching and learning and exploring student engagement in diverse platforms.
Fhloinn & Fitzmaurice (2022) <i>Any advice? Lessons learned by mathematics lecturers for emergency remote teaching during the COVID-19 pandemic</i>	QL	Ireland	Studying the experiences of university mathematics lecturers facing distance teaching methods during the Covid-19 pandemic.
Author (year) and Title of Articles	Research approach	Country	Purpose of the study
Fujita et al. (2021) <i>Japanese teachers' mental readiness for online teaching</i>	QN	Japan	Studying the readiness of teachers in Japan to face online teaching

			<i>of mathematics following unexpected school closures</i>	with some contingency factors during the Covid-19 pandemic.
Gehrtz et al (2022)	QL	United States of America	<i>Learning at a distance: can at-home activities measure up?</i>	Examining the extent to which pedagogy is appropriate for collaborative learning and student engagement.
Giberti et al (2022)	QN	Italy	<i>Exploring students' mathematical discussions in a multi-level hybrid learning environment</i>	Studying the extent of the development of mathematics in hybrid learning and how students cope with it.
Golding & Bretscher (2018)	QL	England	<i>Developing pedagogies for a synchronous online course on teaching pre-university mathematics</i>	Studying the development of online synchronous teaching pedagogy for a pre-university mathematics course.
Goulart et al (2021)	QL	Brazil	<i>An Analysis of the Influences of a Hybrid Learning Environment in the Solution of Vector Tasks According to the Anthropological Theory of the Didactic (ATD)</i>	Studying the influence of a hybrid learning environment in solving vector assignments according to Didactic Anthropology Theory (ATD).
Jeong et al (2020)	QN	Spain	<i>Sustainable and Flipped STEM Education: Formative Assessment Online Interface for Observing Pre-Service Teachers' Performance and Motivation</i>	Reviewing the performance and motivation of pre-service teachers at universities for STEM courses in formative assessment.
Author (year) and Title of Articles	Research approach	Country	Purpose of the study	
Kier & Johnson (2022)	QL	United States of America	<i>Exploring How Secondary STEM Teachers and Undergraduate Mentors Adapt Digital Technologies to Promote Culturally Relevant Education during COVID-19</i>	Examines how partnerships between middle and high school teachers in urban school districts and undergraduate STEM mentors of color leverage digital tools and collaborative pedagogy to teach science, technology, and engineering during a global pandemic.

Kurianski et al (2022) <i>Tools for humanizing mathematics classes in a virtual world (and beyond)</i>	QL	United States of America	Experiment with creative learning methods to bring virtual math classes to life.
Lambert & Alony (2018) <i>Embedding MOOCs in Academic Programmes as a Part of Curriculum Transformation: A Pilot Case Study</i>	QL	Australia	Examining the effectiveness of MOOCs as an alternative method to assist student learning in mathematics.
Le Pichon et al (2021) <i>Using a web-based multilingual platform to support elementary refugee students in mathematics</i>	MM	Canada	Reviewing the implementation of a new web-based multilingual learning platform. A pilot study was conducted to examine the implementation elements and the potential impact of the platform seen in mathematics.
Muirhead et al (2018) <i>Reflections On The Learning Management System: After Two Decades How Has It Effected Our Teaching And Learning Practices?</i>	QL	Canada	Studying the effectiveness of using the Learning Management System (LMS) in teaching and learning.
Musabirov et al (2019) <i>Predictors of Academic Achievement in Blended Learning: The Case of Data Science Minor</i>	QN	Russia	Studying learning behavior patterns related to educational achievement in the minor specialization of Bachelor of Data Science multi-year for non-STEM students Analyzing academic achievement in blended learning by taking into account factors related to prior knowledge of mathematics, specific Education programs, student learning involvement in online or offline.
Author (year) and Title of Articles	Research approach	Country	Purpose of the study
Nair & Nair (2021) <i>Analysis of student satisfaction in the current online teaching scenario</i>	QN	India	Studying the level of student satisfaction in online pursuit and learning scenarios.

Panisoara et al (2020) <i>The effects of online teaching on students' academic progress in stem</i>	QN	Romania	Examine the challenges and concerns felt by teachers when teaching online due to the Covid-19 pandemic and analyzes the impact of the risks they face on meeting basic education standards across each STEM discipline (mathematics, technology, informatics, biology, chemistry, physics, and geography).
Pavlysh et al (2021) <i>Developing a Method for Measuring Science and Technology Oriented Creativity (STOC)</i>	QN	Belarus	Developing instruments to assess student progress creativity as one of the main goals of Science, Technology, Innovation, Mathematics, Engineering for the Young (STIMEY)
Pocsova et al. (2021) <i>The Impact of the COVID-19 Pandemic on Teaching Mathematics and Students' Knowledge, Skills, and Grades</i>	QN	Slovakia	Redesigning the educational process from face-to-face to distance learning in the Mathematics 1 course at the Technical University of Košice using our approach to teaching, observation and experience.
Pourdavood & Song (2021) <i>Engaging pre-service and in-service teachers in online mathematics teaching and learning: Problems and possibilities</i>	QL	United States of America	Examining factors, such as interaction, communication, and peer support impact pre-service and in-service mathematics teachers' beliefs and practices toward online teaching and learning.
Rasheed et al (2021) <i>An Approach for Scaffolding Students Peer-Learning Self-Regulation Strategy in the Online Component of Blended Learning</i>	QN	Malaysia	Examining approaches to self-regulatory strategies of peer learning in the online component of blended learning.
Author (year) and Title of Articles	Research approach	Country	Purpose of the study

Rocha et al (2022) <i>What makes online teaching spatial? Examining the connections between K-12 teachers' spatial skills, affect, and their use of spatial pedagogy during remote instruction</i>	MM	United States of America	Examining differences in skills and concerns between teachers working at the primary versus secondary levels, examining the relationship between their skills and concerns taking into account additional influencing factors—general reasoning ability and general concerns and examining how teachers' skills in conjunction with their concerns relate to the use of spatial teaching practices for online teaching.
Segerby (2022) <i>Exploring How a University Mathematics Teacher's Digital Relational Competence Can Be Manifested: A Micro-Analytical Study</i>	MM	Sweden	Examining teacher-student relationships in online teaching.
Shaw & Tranter (2021) <i>Levelling the playing field in assessment: an analysis of attainment gaps for widening participation, black and minority ethnic mathematics undergraduates before and after the COVID-19 lockdown</i>	MM	United Kingdom	Examined the achievement gap issue and found that the achievement gap was closed in this cohort for black and minority ethnic students but that students from lower socio-economic backgrounds may have been disadvantaged by the shift to online teaching, learning and assessment methods.
Singh-Pillay & Naidoo (2020) <i>Context Matters: Science, Technology And Mathematics Education Lecturers' Reflections On Online Teaching And Learning During The Covid-19 Pandemic</i>	QL	South Africa	Surveying the reflections of STEM lecturers on the use of online technology and the factors that enable or constrain online teaching and learning.
Trenholm et al. (2019) <i>A Review of Fully Online Undergraduate Mathematics Instruction through the Lens of Large-Scale Research (2000-2015)</i>	QL	Australia	Studies that fully online teaching can promote a deeper and richer conceptual understanding of mathematical ideas while others claim that it is difficult to teach mathematics effectively in a fully online context.

Author (year) and Title of Articles	Research approach	Country	Purpose of the study
Van Nuland et al (2020) <i>STEM crisis teaching: Curriculum design with e-learning tools</i>	QL	United States of America	Review the methods that should be used by educators for teaching and integrating learning tools in the curriculum.
Wang (2021) <i>A Theoretical Analysis Method of Spatial Analytic Geometry and Mathematics under Digital Twins</i>	MM	China	Examining dissatisfaction about the quality of online teaching, the effects of online student learning and students' very weak learning autonomy abilities.
Wang et al (2021) <i>Analysis of Blended Learning Model Application Using Text Mining Method</i>	QL	Malaysia	Analyzing the application of the blended learning model (blended learning) using the Text Mining method.
Wang (2022) <i>PLS-SEM Model of Integrated Stem Education Concept and Network Teaching Model of Architectural Engineering Course</i>	QN	China	Studying methods to apply the concept of STEM education in architectural engineering teaching through literature analysis and architectural engineering teaching case design.
Wu et al (2021) <i>Student's Learning Strategies and Academic Emotions: Their Influence on Learning Satisfaction During the COVID-19 Pandemic</i>	QN	China	Examining student learning strategies affecting performance and emotions during the Covid-19 pandemic.

Results and Discussions

The main objective of this study is to identify trends in the implementation of hybrid teaching and learning in mathematics education based on the year of publication, research approach, author's country, and the purpose of the study. This study obtained a total of 41 research articles that have an important relationship with the topic of this study. This literature review provides a valuable contribution to scholars or researchers by providing them with a critical assessment of existing research on the research topic. Next, an analysis of the year of publication, research approach, author's country, and the purpose of the study can help scholars or researchers in the future.

To identify the trends in the implementation of hybrid teaching and learning in mathematics education based on the year of publication.

Figure 2 shows the context of the year of publication, 18 articles were published in 2021 (Aristika, A et al., 2021; Ashraf et al., 2021; Batra et al., 2021, Bouck & Long, 2021; Cao et al., 2021; Church et al., 2021; Fujita et al., 2021; Goulart et al., 2021; Le Pichon et al., 2021; Nair & Nair, 2021; Pavlysh et al., 2021; Pócsová et al., 2021; Pourdavood & Song, 2021; Rasheed et

al., 2021; Shaw & Tranter, 2021; Wang, KQ 2021; K. Wang, 2021; Wu et al., 2021), followed by 12 articles published in 2022 (Brunetto et al., 2022; Cavanaugh et al., 2022; DeCoito & Estaiteyeh, 2022; Durandt et al., 2022; Ní Fhloinn & Fitzmaurice, 2022; Gehrtz et al., 2022; Giberti et al., 2022; Kier & Johnson, 2022; Kurianski et al., 2022; Rocha et al., 2022; Segerby, 2022; P. Wang, 2022), 5 articles in 2020 (Bakar, Mohamad & Ismail, 2020; Jeong et al., 2020; Panisoara et al., 2020; Singh-Pillay & Naidoo, 2020; Van Nuland et al., 2020), 4 articles in 2018 (Chen & Huang, 2018; Golding & Bretscher, 2018; Lambert & Alony, 2018; Muirhead et al., 2018) and finally 2 articles have been published in 2019 (Musabirov et al., 2019; Trenholm et al., 2019).

The year with the highest number of published articles was 2021. This shows that this year all countries in the world have been hit by the Covid-19 pandemic and most educational institutions have been ordered to close to curb the spread of Covid-19. The teaching and learning implementation method has changed from face-to-face to online or hybrid to ensure that education at the level from pre-school to higher education continues without dropouts even though the entire country is being hit by the Covid-19 pandemic.

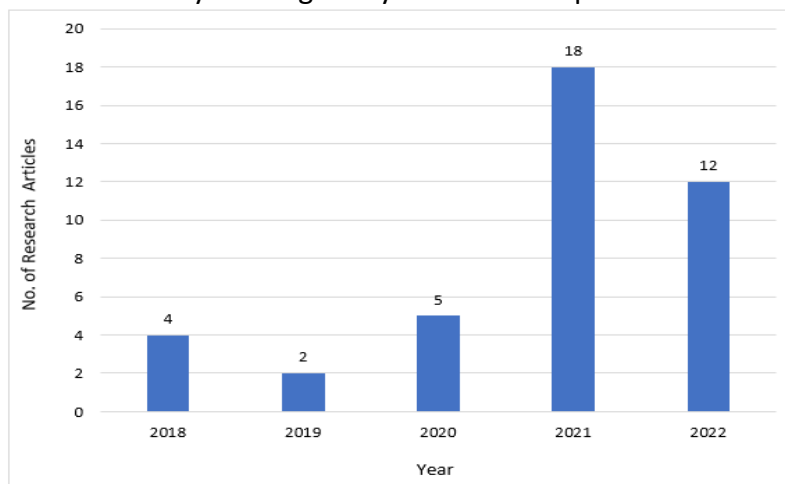


Figure 2 Trends in the implementation of hybrid teaching and learning in mathematics education based on the year of publication.

To identify the trend of implementing hybrid teaching and learning in mathematics education based on the research approach.

Methodology in research is a scientific method to describe the method or approach used in research. In general, research approaches can be divided into two, namely quantitative and qualitative. Based on Figure 3 shows the research approach that can be analyzed from 41 articles in this study where the highest is using a qualitative research approach of 19 articles (Ashraf et al., 2021; Bakar et al., 2020; Batra et al., 2021; Bouck & Long, 2021; Brunetto et al., 2022; Church et al., 2021; Ní Fhloinn & Fitzmaurice, 2022; Gehrtz et al., 2022; Golding & Bretscher, 2018; Goulart et al., 2021; Kier & Johnson, 2022; Kurianski et al., 2022; Lambert & Alony, 2018; Muirhead et al., 2018; Pourdavood & Song, 2021; Singh-Pillay & Naidoo, 2020; Trenholm et al., 2019; Nuland et al., 2020; Wang et al., 2020), 16 articles use a quantitative research approach (Aristika et al., 2021; Cao et al., 2021; Cavanaugh et al., 2022; Chen & Huang, 2018; Durandt et al., 2022; Fujita et al., 2021; Giberti et al., 2022; Jeong et al., 2020; Musabirov et al., 2019; Nair & Nair, 2021; Panisoara et al., 2020; Pavlysh et al., 2021; Pócsová et al., 2021; Rasheed et al., 2021; P. Wang, 2022; Wu et al., 2021) and 6 articles using a mixed

method research approach (DeCoito & Estaiteyeh, 2022; Le Pichon et al., 2021; Rocha et al., 2022; Segerby, 2022; Shaw & Tranter, 2021; Wang, 2021).

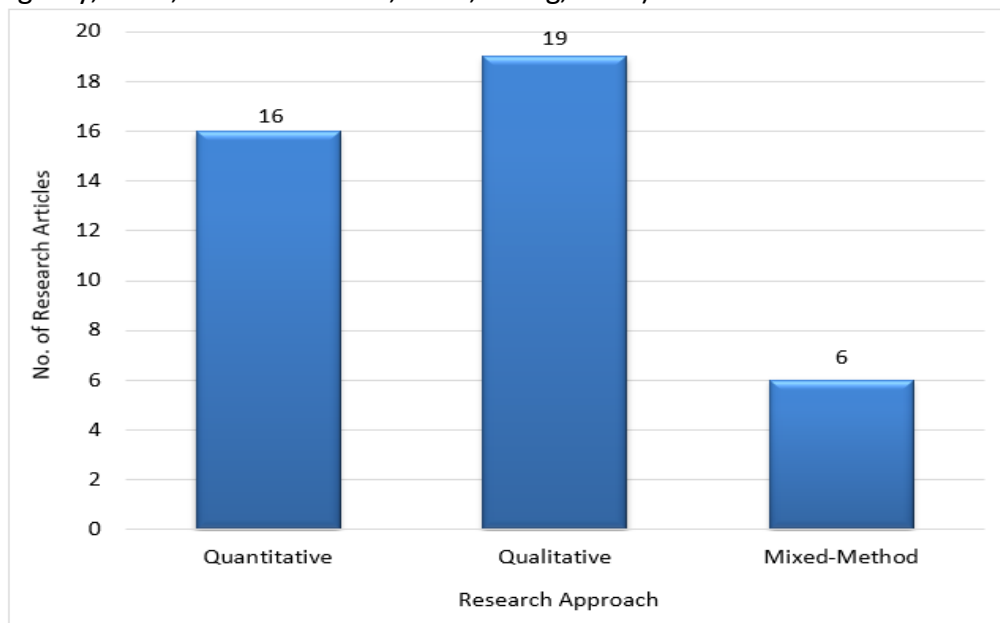


Figure 3 Trends in the implementation of hybrid teaching and learning in mathematics education based on a research approach.

The qualitative approach is the highest in the publication of articles. This shows that this research approach is the best choice for researchers to study the implementation of hybrid teaching and learning in mathematics education. For example, this approach is best for conducting effective technology platform interventions that include a variety of age and skill levels and math concepts (Bouck & Long, 2021). While Goulart et al (2021) also used a qualitative approach because it is easier to study the influence of a hybrid learning environment in solving vector assignments according to the Anthropological Theory of the Didactic (ATD).

However, based on the analysis of the research approach carried out, it shows that the United States has the highest record of conducting qualitative research, China has recorded the most elevated quantitative research design, and Canada has the highest record of conducting a combined research approach that is quantitative and qualitative.

Table 5

Hybrid teaching and learning implementation trends in mathematics education by country.

No. of articles Country	Research Approach		
	Quantitative	Qualitative	Mixed-method
Amerika Syarikat (9)	1	7	1
Afrika Selatan (2)	1	1	-
Australia (2)	-	2	-
Belarus (1)	1	-	-
Brazil (1)	-	1	-
China (6)	4	1	1

England (1)	-	1	-
India (2)	1	1	-
Indonesia (1)	1	-	-
Ireland (1)	-	1	-
Itali (2)	1	1	-
Jepun (1)	1	-	-
Kanada (3)	-	1	2
Malaysia (3)	1	2	-
Romania (1)	1	-	-
Rusia (1)	1	-	-
Sepanyol (1)	1	-	-
Slovakia (1)	1	-	-
Sweden (1)	-	-	1
United Kingdom	-	-	1

Based on Table 5, it is found that the United States uses the qualitative approach the most, this is because the researcher will rely on the views of the respondents. Usually, the researcher will ask broad and general questions. They will also collect data in word or text form from their respondents. This qualitative method also obtained cannot be generalized. It is an exploratory study or understanding of the main phenomenon and has a general purpose and is based on the experience of the respondents the data collection is in the form of text/pictures and involves a small number of respondents. While China recorded the highest number using a quantitative approach because it is a study that generally uses statistical analysis and is more objective and result oriented. This method is often associated with data numbers, accuracy, and descriptive or explanatory from the specific and focused where it can be measured or observed also involving many respondents.

To identify the trend of implementation of hybrid teaching and learning in mathematics education based on the country.

Several countries have conducted studies on hybrid teaching and learning in mathematics education at either the primary or higher education levels. Based on Figure 4 shows the country of origin identified and analyzed to show the country trends in the publication of this high-impact journal. Researchers have identified 20 countries, namely the United States (9), China (6), Malaysia (3), Canada (3), Italy (2), India (2), Australia (2), South Africa (2), Belarus (1), Brazil (1), Indonesia (1), Ireland (1), Japan (1), England (1), Romania (1), Russia (1), Spain (1), Slovakia (1), Sweden (1) and the United Kingdom (1). The numbers displayed to show the number of publications according to each country. However, our results found that there are 13 studies for 10 countries related to the implementation of teaching and learning during the Covid-19 pandemic, namely the United States, South Africa, China, India, Italy, Ireland, Canada, Romania, Slovakia, and the United Kingdom.

The United States appears in the top position in contributing to the publication of articles (Bouck & Long, 2021; Cavanaugh et al., 2022; Church et al., 2021; Gehrtz et al., 2022; Kier & Johnson, 2022; Kurianski et al., 2022; Pourdavood & Song, 2021; Rocha et al., 2022; Van Nuland et al., 2020). Although the United States recorded the highest record, researchers from the same institution and some from different institutions.

Furthermore, six studies have been published on hybrid teaching and learning in China which is known to be a country that has been very affected by the Covid-19 pandemic (Ashraf et al., 2021; Cao et al., 2021; Cao et al., 2021; Wang, 2021; Wang, 2022; Wu et al., 2021), three studies focused on Canada (DeCoito & Estaiteyeh, 2022; Le Pichon et al., 2021; Muirhead et al., 2018), Malaysia (Bakar et al., 2020; Rasheed et al., 2021; Wang et al., 2020), two studies focused on South Africa (Durandt et al., 2022; Singh-Pillay & Naidoo, 2020), India (Batra et al. al., 2021; Nair & Nair, 2021), Italy (Brunetto et al., 2022; Giberti et al., 2022), Australia (Lambert & Alony, 2018; Trenholm et al., 2019).

Meanwhile, one study focused on Belarus (Pavlysh et al., 2021), Brazil (Goulart et al., 2021), Indonesia (Aristika et al., 2021), Ireland (Ní Fhloinn & Fitzmaurice, 2022), Japan (Ní Fhloinn & Fitzmaurice, 2022), England (Golding & Bretscher, 2018), Romania (Panisoara et al., 2020), Russia (Musabirov et al., 2019), Spain (Jeong et al., 2020), Slovakia (Pócsová et al., 2021), Sweden (Segerby, 2022) and United Kingdom (Shaw & Tranter, 2021).

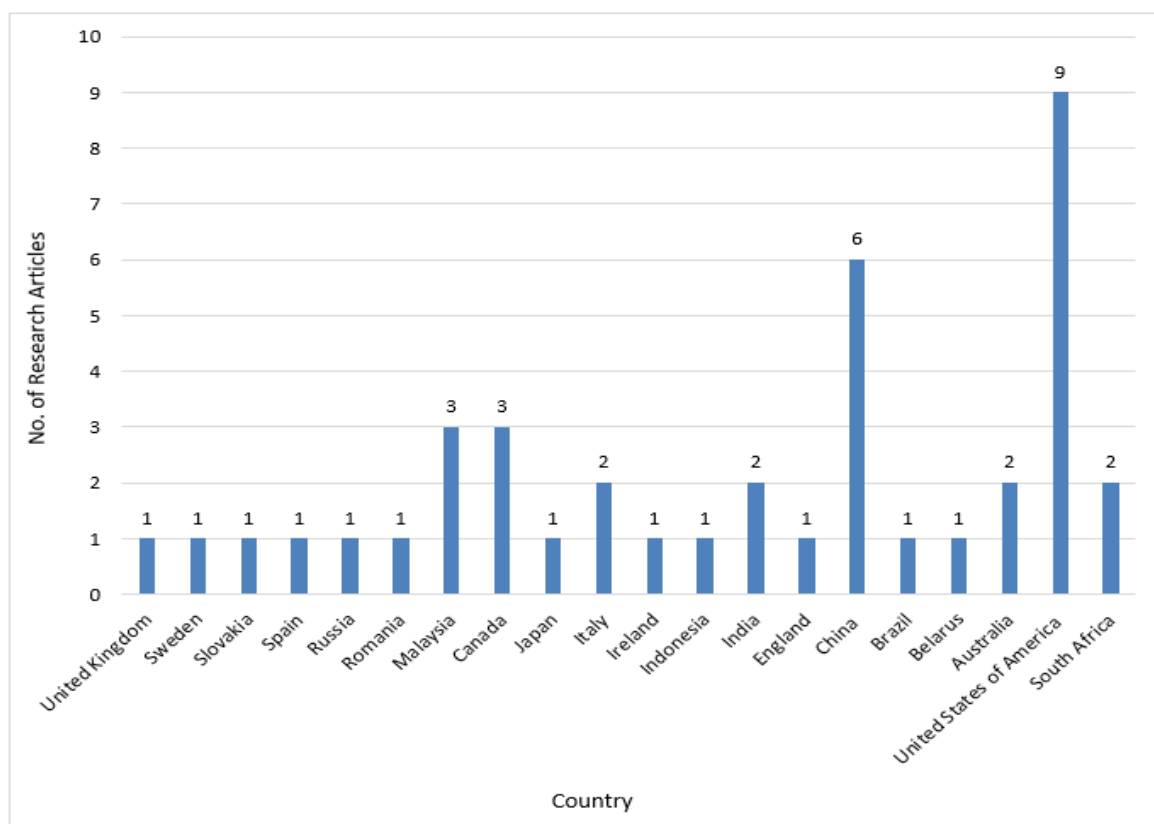


Figure 4 Trends in the publication of articles on the implementation of hybrid teaching and learning in mathematics education based on the researcher's country of origin.

Based on the analysis that has been carried out, the United States and China recorded the publication of a high number of articles compared to other countries. This is because both countries have been greatly affected by the spread of the Covid-19 virus that has hit all countries in the world. Therefore, the Covid-19 pandemic has affected the education system of the entire country, especially the two countries, namely the United States and China, compared to other countries. Therefore, research into education that focuses on the implementation of online teaching and learning is very important during the pandemic to ensure that the education system is not adversely affected by future generations in general

and is no exception also in mathematics education which is always a major subject around the world.

To Identify the teaching and learning implementation trend in mathematics education based on the purpose of the study

Research has a specific rationale for contributing to the construction of new knowledge and can help solve problems faced in life. The purpose of the study is to find answers to the questions of the problem statement by the researcher which is a statement about the overall direction or focus of a study. In addition, a clear purpose of the study can also help identify the design or approach of the study that is suitable to be used.

Figure 5 shows the trend analysis of the implementation of teaching and learning in mathematics education based on the purpose of each study. The researcher has identified the purpose of the study that has been carried out which is 14 research articles related to the implementation of online teaching and learning Durandt et al (2022); Ní Fhloinn & Fitzmaurice, (2022); Fujita et al (2021); Lambert & Alony (2018); Le Pichon et al (2021); Muirhead et al (2018); Nair & Nair (2021); Rasheed et al (2021); Segerby (2022); Shaw & Tranter (2021); Trenholm et al (2019); Van Nuland et al (2020); Wang (2021); Wu et al (2021), eight articles aimed at studying teaching methods in Science, Technology, Engineering and Mathematics Church et al (2021); DeCoito & Estaiteyeh (2022); Jeong et al (2020); Kier & Johnson (2022); Panisoara et al (2020); Singh-Pillay & Naidoo (2020); Wang (2022), five articles aimed at studying pedagogical practices Brunetto et al (2022); Gehrtz et al (2022); Golding & Bretscher (2018); Kurianski et al (2022); Pócsová et al (2021), four articles aimed at studying hybrid teaching and learning Aristika et al (2021); Ashraf et al (2021); Goulart et al (2021); Giberti et al (2022), three articles aimed at examining the factors influencing online teaching and learning (Pourdavood & Song, 2021; Chen & Huang, 2018; Rocha et al., 2022), three articles aimed at studying related to developing mathematics teaching models (Bakar, Mohamad & Ismail, 2020; L. Wang et al., 2020; Pavlysh et al., 2021;), two articles aim to examine students' perceptions of online teaching and learning (Batra et al., 2021; Cavanaugh et al., 2022), one article aims to study teachers' perceptions of online teaching and learning (Cao et al., 2021) and one article aimed at studying interventions in teaching and learning (Bouck & Long, 2021).

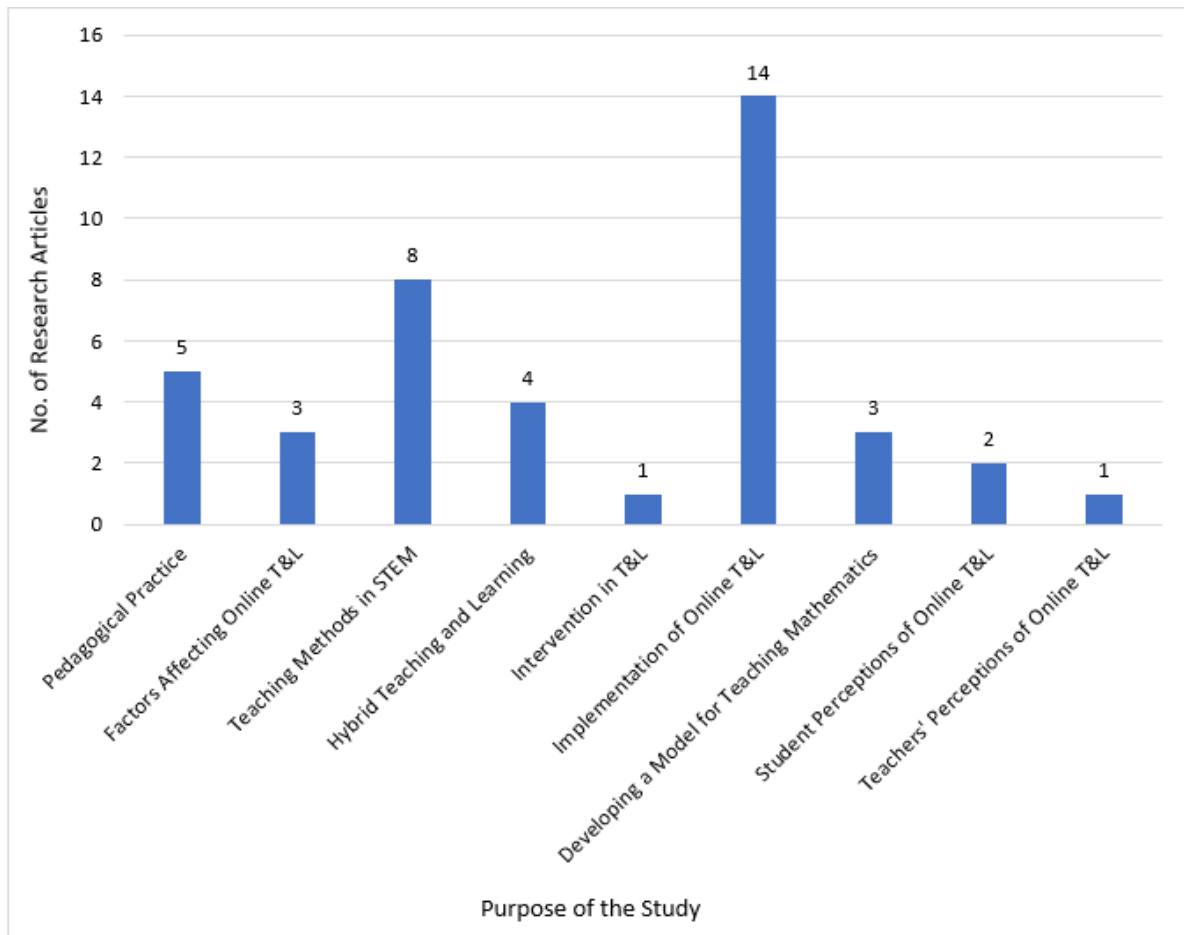


Figure 5 Trends in the publication of articles on the implementation of hybrid teaching and learning in mathematics education based on the purpose of the study.

Based on the analysis of the purpose of the study of all articles that have been published, it can generally be seen that the purpose of the study carried out is related to teaching and learning online because the 2018-2022 period includes the period of the Covid-19 pandemic. It is known that in 2020-2021, the world has been hit by the Covid-19 epidemic and at the same time it had an impact on the world education system in general and mathematics education in particular. Usually, the teaching and learning process for mathematics subjects before the pandemic was carried out face-to-face and was easier and able to have a positive impact on students compared to during the pandemic. During the pandemic period, teaching and learning will no longer be carried out face-to-face to protect the safety of teachers and students as well as to curb the spread of Covid-19. Because of that, many researchers conduct studies to find out the problems that arise related to the implementation of online teaching and learning, especially in the subject of mathematics. Among the purposes of the study that can be analyzed are related to the implementation of hybrid teaching and learning, the implementation of online teaching and learning, factors that affect online teaching and learning, and teaching methods in Science, Technology, Engineering, and Mathematics (STEM), teaching and learning interventions online as well as students' and teachers' perceptions of the implementation of online teaching and learning.

Conclusion

The findings of this study show that a new chapter in the world of education when the pandemic hits where there is a combination of online teaching and learning approaches and traditional approaches in the classroom. According to Karimi et al (2013), combined face-to-face and online teaching and learning approaches are known as hybrid approaches. In principle, students will be able to use information and communication technology practically and this hybrid approach can improve the lack of traditional and online teaching and learning.

Based on Table 4, the purpose of the study found in this analysis can be seen in that most articles focus more on online teaching and learning. This study has several implications such as the implementation of hybrid teaching and learning is also one of the methods that is closely related to the use of information and communication technology. So, 14 articles that can be identified discuss the findings regarding online teaching and learning, among which there are researchers who identify blended learning trends among students so that they do not drop out and learn actively and improve their learning outcomes. The power of blended learning can also be used for self-learning with peers and using the Text-Mining method. This online teaching and learning can also be identified as requiring a high level of readiness by teachers and students to ensure a level of academic achievement of good quality and the ability to improve learning for weak students. Various mediums are used synchronously and asynchronously such as Learning Management Systems (LMS), and Massive Open Online Courses (MOOCs) which are alternative online methods including videos, text content, discussion forums, and verifying their achievements with training. Based on further research, mathematics education can be expanded when students and teachers can adapt hybrid learning very well and there are also researchers who use this hybrid teaching and learning to complete vector assignments using Didactic Anthropology Theory.

This study can be improved through the study of several factors that affect online teaching using integrated technology acceptance methods and cognitive theory. In addition, factors such as interaction, communication, and peer support also have a profound effect on students facing online teaching and learning. According to Bakar (2020), it is necessary to develop an online mathematics teaching model that integrates metacognitive learning strategies. To assess the creativity of student progress, an instrument has been developed to assess the creativity of student progress as one of the main targets in Science, Technology, Innovation, Mathematics, Engineering for the Young (STIMEY).

With the implementation of hybrid teaching and learning in mathematics education, teachers and students need to know more deeply how it is carried out. According to Prasojo & Srisudarso (2021), hybrid learning can provide opportunities for teachers and students to conduct synchronous and asynchronous interactions. The combination of traditional and online teaching and learning approaches has opened a new breath to the world of Education so that students who want to be born meet the National Mission and Aspiration. The hybrid teaching and learning approach is seen to provide opportunities and space for students to increase their potential. However, it is suggested that further studies can be carried out to study hybrid teaching and learning in Mathematics Education carefully such as studies on teaching and learning after the pandemic are conducted so that the difference in learning outcomes can be seen. So, for that reason, this study suggests to relevant parties such as the

Malaysian Ministry of Education to pay due attention to empowering the education system towards industrial revolution 4.0 and researchers are confident that the application of technology skills in teaching and learning will be at this level which will be even better in the future.

Corresponding Author

Mohd Effendi @ Ewan Mohd Matore (Ph.D)

Faculty of Education, National University of Malaysia, 43600 UKM Bangi, Selangor, Malaysia.

Email: effendi@ukm.edu.my

Acknowledgment

I would like to acknowledge and express my gratitude to my supervisor, Associate Professor Ts. Dr. Mohd Effendi @ Ewan Mohd Matore for his relentless contribution to this study at every stage. I am also immensely thankful to my family for their ongoing support and understanding when writing this review paper.

References

- Aristika, A., Darhim, Juandi, D., & Kusnandi. (2021). The effectiveness of hybrid learning in improving of teacher-student relationship in terms of learning motivation. *Emerging Science Journal*, 5(4), 443–456. <https://doi.org/10.28991/esj-2021-01288>
- Ashraf, M. A., Yang, M., Zhang, Y., Denden, M., Tlili, A., Liu, J., Huang, R., & Burgos, D. (2021). A systematic review of systematic reviews on blended learning: Trends, gaps and future directions. *Psychology Research and Behavior Management*, 14, 1525–1541. <https://doi.org/10.2147/PRBM.S331741>
- Bakar, Mohamad & Ismail, N. (2020). *Metacognitive online discussion for online teaching: A conceptual and impact on students engagement and mastery during coronavirus outbreaks*. 6(1), 61–64.
- Batra, S., Sharma, S. R., Kumra, N., & Gupta, M. (2021). Traditional vs e-teaching learning due to covid-19: A case study for mathematics course. *Journal of Engineering Education Transformations*, 35(1), 80–87. <https://doi.org/10.16920/jeet/2021/v35i1/154401>
- Bouck, E. C., & Long, H. (2021). Online Delivery of a Manipulative-Based Intervention Package for Finding Equivalent Fractions. *Journal of Behavioral Education*, 0123456789. <https://doi.org/10.1007/s10864-021-09449-y>
- Brunetto, D., Bernardi, G., Andrà, C., & Liljedahl, P. (2022). Teaching as a system: COVID-19 as a lens into teacher change. *Educational Studies in Mathematics*, 110(1), 65–81. <https://doi.org/10.1007/s10649-021-10107-3>
- Cao, Y., Zhang, S., Chan, M. C. E., & Kang, Y. (2021). Post-pandemic reflections: lessons from Chinese mathematics teachers about online mathematics instruction. *Asia Pacific Education Review*, 22(2), 157–168. <https://doi.org/10.1007/s12564-021-09694-w>
- Cavanaugh, J., Jacquemin, S. J., & Junker, C. R. (2022). Variation in Student Perceptions of Higher Education Course Quality and Difficulty as a Result of Widespread Implementation of Online Education During the COVID-19 Pandemic. *Technology, Knowledge and Learning*, 0123456789. <https://doi.org/10.1007/s10758-022-09596-9>
- Chen, J. F., & Huang, H. F. (2018). Empirical study on the factors influencing the web-based teaching effect. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(5), 1635–1643. <https://doi.org/10.29333/EJMSTE/85035>

- Church, F. C., Cooper, S. T., Fortenberry, Y. M., Glasscock, L. N., & Hite, R. (2021). Useful teaching strategies in stemm (Science, technology, engineering, mathematics, and medicine) education during the covid-19 pandemic. *Education Sciences*, 11(11). <https://doi.org/10.3390/educsci11110752>
- DeCoito, I., & Estaiteyeh, M. (2022). Transitioning to Online Teaching During the COVID-19 Pandemic: an Exploration of STEM Teachers' Views, Successes, and Challenges. *Journal of Science Education and Technology*, 31(3), 340–356. <https://doi.org/10.1007/s10956-022-09958-z>
- Durandt, R., Herbst, S., & Seloane, M. (2022). Teaching and learning first-year engineering mathematics at a distance: A critical view over two consecutive years. *Perspectives in Education*, 40(1), 143–163. <https://doi.org/10.18820/2519593X/PIE.V40.I1.9>
- Fujita, T., Nakagawa, H., Sasa, H., Enomoto, S., Yatsuka, M., & Miyazaki, M. (2021). Japanese teachers' mental readiness for online teaching of mathematics following unexpected school closures. *International Journal of Mathematical Education in Science and Technology*. <https://doi.org/10.1080/0020739X.2021.2005171>
- Gehertz, J., Vallines Mira, R., Duffer, C., & Prasad, P. V. (2022). Learning at a distance: can at-home activities measure up? *International Journal of Mathematical Education in Science and Technology*, 53(3), 689–697. <https://doi.org/10.1080/0020739X.2021.1985180>
- Giberti, C., Arzarello, F., Bolondi, G., & Demo, H. (2022). Exploring students' mathematical discussions in a multi-level hybrid learning environment. *ZDM - Mathematics Education, March 2020*. <https://doi.org/10.1007/s11858-022-01364-4>
- Golding, J., & Bretscher, N. (2018). Developing pedagogies for a synchronous online course on teaching pre-university mathematics. *Teaching Mathematics and Its Applications*, 37(2), 98–112. <https://doi.org/10.1093/teamat/hry010>
- Goulart, J. S. S., Farias, L. M. S., & Chaachoua, H. (2021). An Analysis of the Influences of a Hybrid Learning Environment in the Solution of Vector Tasks According to the Anthropological Theory of the Didactic (ATD). *Mathematics Enthusiast*, 18(3), 669–700. <https://doi.org/10.54870/1551-3440.1540>
- Jeong, J. S., Gonzalez-Gomez, D., & Prieto, F. Y. (2020). Sustainable and flipped stem education: Formative assessment online interface for observing pre-service teachers' performance and motivation. *Education Sciences*, 10(10), 1–14. <https://doi.org/10.3390/educsci10100283>
- Jeroen, B., Michiel, S., Andrew, P., Gregoire, C. & Reza Karimi. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, 1(1), 377-386.
- Karimi, L., Ahmad, B. T. T., & Khodabandelou, R. (2013). Sense of community and English perceived learning in a social networking site: A study of Facebook. *International Journal of E-Education, e-Business, e- Management, and e-Learning*, 3(3), 224–228.
- Kier, M. W., & Johnson, L. L. (2022). Exploring How Secondary STEM Teachers and Undergraduate Mentors Adapt Digital Technologies to Promote Culturally Relevant Education during COVID-19. *Education Sciences*, 12(1). <https://doi.org/10.3390/educsci12010048>
- Kurianski, K. M., Marzocchi, A. S., & Soto, R. C. (2022). Tools for humanizing mathematics classes in a virtual world (and beyond). *International Journal of Mathematical Education in Science and Technology*, 53(3), 698–707. <https://doi.org/10.1080/0020739X.2021.1985178>

- Lambert, S., & Alony, I. (2018). *Embedding MOOCs in Academic Programmes as a Part of Curriculum Transformation: A Pilot Case Study*. 73–81. https://doi.org/10.1007/978-981-10-7995-5_7
- Le Pichon, E., Cummins, J., & Vorstman, J. (2021). Using a web-based multilingual platform to support elementary refugee students in mathematics. *Journal of Multilingual and Multicultural Development*, *0*(0), 1–17. <https://doi.org/10.1080/01434632.2021.1916022>
- Muirhead, B., Robertson, L., & Vogel, E. (2018). Reflections on the Learning Management System: After Two Decades How Has It Effected Our Teaching and Learning Practices? *INTED2018 Proceedings*, *1*, 2839–2846. <https://doi.org/10.21125/inted.2018.0533>
- Musabirov, I., Pozdniakov, S., & Tenisheva, K. (2019). Predictors of academic achievement in blended learning: The case of data science minor. *International Journal of Emerging Technologies in Learning*, *14*(5), 64–74. <https://doi.org/10.3991/ijet.v14i05.9512>
- Nair, A., & Nair, R. K. R. (2021). Analysis of student satisfaction in the current online teaching scenario. *Journal of Engineering Education Transformations*, *34*(Special Issue), 566–573. <https://doi.org/10.16920/jeet/2021/v34i0/157214>
- Ni Fhloinn, E., & Fitzmaurice, O. (2022). Any advice? Lessons learned by mathematics lecturers for emergency remote teaching during the COVID-19 pandemic. *International Journal of Mathematical Education in Science and Technology*, *53*(3), 566–572. <https://doi.org/10.1080/0020739X.2021.1983049>
- Panisoara, I. O., Chirca, R., & Lazar, I. (2020). The effects of online teaching on students' academic progress in stem. *Journal of Baltic Science Education*, *19*(6), 1106–1124. <https://doi.org/10.33225/JBSE/20.19.1106>
- Pavlysh, E. V., Astapchuk, S. V., Reid, A. A. M., Rio, C. R. Del, Mäkelä, T., Fenyvesi, K., Pnevmatikos, D., Christodoulou, P., & Mäkiö, J. (2021). Developing a Method for Measuring Science and Technology Oriented Creativity (STOC). *Open Education Studies*, *3*(1), 212–225. <https://doi.org/10.1515/edu-2020-0155>
- Pocsova, J., Mojzisova, A., Takac, M., & Klein, D. (2021). The impact of the covid-19 pandemic on teaching mathematics and students' knowledge, skills, and grades. *Education Sciences*, *11*(5). <https://doi.org/10.3390/educsci11050225>
- Pourdavood, R. G., & Song, X. (2021). Engaging pre-service and in-service teachers in online mathematics teaching and learning: Problems and possibilities. *International Journal of Learning, Teaching and Educational Research*, *20*(11), 96–114. <https://doi.org/10.26803/ijlter.20.11.6>
- Rasheed, R. A., Kamsin, A., & Abdullah, N. A. (2021). An approach for scaffolding students peer-learning self-regulation strategy in the online component of blended learning. *IEEE Access*, *9*, 30721–30738. <https://doi.org/10.1109/ACCESS.2021.3059916>
- Rocha, K., Lussier, C. M., & Atit, K. (2022). What makes online teaching spatial? Examining the connections between K-12 teachers' spatial skills, affect, and their use of spatial pedagogy during remote instruction. *Cognitive Research: Principles and Implications*, *7*(1). <https://doi.org/10.1186/s41235-022-00377-7>
- Segeberby, C. (2022). Exploring How a University Mathematics Teacher's Digital Relational Competence Can Be Manifested: A Micro-Analytical Study. *Education Sciences*, *12*(4). <https://doi.org/10.3390/educsci12040257>
- Shaw, L. M., & Tranter, M. R. (2021). Levelling the playing field in assessment: An analysis of attainment gaps for widening participation, black and minority ethnic mathematics

- undergraduates before and after the COVID-19 lockdown. *Teaching Mathematics and Its Applications*, 40(4), 497–505. <https://doi.org/10.1093/teamat/hrab024>
- Singh-Pillay, A., & Naidoo, J. (2020). Context matters: Science, technology and mathematics education lecturers' reflections on online teaching and learning during the covid-19 pandemic. *Journal of Baltic Science Education*, 19(6), 1125–1136. <https://doi.org/10.33225/JBSE/20.19.1125>
- Trenholm, S., Peschke, J., & Chinnappan, M. (2019). A Review of Fully Online Undergraduate Mathematics Instruction through the Lens of Large-Scale Research (2000-2015). *Primus*, 29(10), 1080–1100. <https://doi.org/10.1080/10511970.2018.1472685>
- Van Nuland, S. E., Hall, E., & Langley, N. R. (2020). STEM crisis teaching: Curriculum design with e-learning tools. *FASEB BioAdvances*, 2(11), 631–637. <https://doi.org/10.1096/fba.2020-00049>
- Wang, K. (2021). A Theoretical Analysis Method of Spatial Analytic Geometry and Mathematics under Digital Twins. *Advances in Civil Engineering*, 2021(2018). <https://doi.org/10.1155/2021/8910274>
- Wang, L., Huang, Y., & Omar, M. K. (2020). Analysis of Blended Learning Model Application Using Text Mining Method. *International Journal of Emerging Technologies in Learning*, 16(1), 172–187. <https://doi.org/10.3991/IJET.V16I01.19823>
- Wang, P. (2022). PLS-SEM Model of Integrated Stem Education Concept and Network Teaching Model of Architectural Engineering Course. *Mathematical Problems in Engineering*, 2022, 1–10. <https://doi.org/10.1155/2022/7220957>
- Wu, C., Jing, B., Gong, X., Mou, Y., & Li, J. (2021). Student's Learning Strategies and Academic Emotions: Their Influence on Learning Satisfaction During the COVID-19 Pandemic. *Frontiers in Psychology*, 12(September), 1–13. <https://doi.org/10.3389/fpsyg.2021.717683>