www.ijemst.net

Enhancing Mathematical Interest through Visual Arts Integration: A Systematic Literature Review

Sisilia Sylviani
Universitas Padjadjaran, Indonesia

Fahmi Candra Permana
Universitas Pendidikan Indonesia, Indonesia

Ahamad Tarmizi Azizan
University of Kelantan Malaysia, Malaysia

To cite this article:

Sylviani, S., Permana, F.C., & Azizan A.T (2024). Enhancing mathematical interest through visual arts integration: A systematic literature review. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 12*(5), 1217-1235. https://doi.org/10.46328/ijemst.4118

International Journal of Education in Mathematics, Science and Technology

2024, Vol. 12, No. 5, 1217-1235 https://doi.org/10.46328/ijemst.4118

Enhancing Mathematical Interest through Visual Arts Integration: A Systematic Literature Review

Sisilia Sylviani, Fahmi Candra Permana, Ahamad Tarmizi Azizan

Article Info

Article History

Received:
December 10, 2023
Accepted:
June 23, 2024

Keywords

Visual art
Mathematics education
Engaging pedagogy
challenge in education

Abstract

This study explores the inclusion of the visual arts in mathematics instruction as a means of piquing students' interest in a topic that is frequently regarded as difficult. We evaluate numerous research that have been undertaken in this situation by completing an extensive literature study. Our findings show that the inclusion of visual arts in mathematics instruction has been helpful in piquing students' attention, boosting their motivation, and creating possibilities for them to investigate challenging mathematical ideas in a more imaginative way. These results provide a deeper understanding of the importance of visual arts in creating an engaging mathematics learning environment. The study also highlights challenges that need to be addressed and provides insights for further development in the application of visual arts in mathematics education. Thus, the integration of visual arts has significant potential to build interest in mathematics and enrich students' learning experiences.

Introduction

In the educational curriculum, mathematics is a crucial topic. The learning process is, however, frequently hampered by a number of difficulties. How to improve pupils' interest in math is one of the major issues. According to several studies, many students "fear" this subject because they frequently find it challenging and boring. This can affect students' learning outcomes and reduce the quality of education at various levels.

Many studies have demonstrated these challenges. (Sullivan et al., 2006) found that students' orientation toward learning mathematics was not predicted by their achievement, indicating that classroom culture may play a role in low participation. (An Bhaird et al., 2013) highlighted that a large number of students are not engaged with mathematics learning support, and the reasons for this lack of engagement vary.) (Ogochukwu, 2010)explored the use of multimedia presentations in mathematics education and found that it can increase students' understanding, enthusiasm, class attendance, and satisfaction. (Ganal & Guiab, 2014) discussed the problems and difficulties faced by students in mastering mathematics learning competencies, including negative attitudes and mathematics anxiety.

Efforts to enhance students' interest in mathematics are crucial for the development of curriculum and learning methods. One approach that has gained attention is the integration of visual arts into mathematics learning. Increasing student involvement and interest in a variety of areas, such as mathematics, has long been seen to be successful with art. Integrating the arts into mathematics teaching holds the potential to enhance student involvement and offer a more holistic approach to learning. This fusion of visual arts into mathematics education aims to bridge what might seem like disparate domains, with the overarching goal of fostering student interest and motivation.

Recent years have witnessed a surge in studies exploring the viability of incorporating visual arts to augment mathematical interest. Preliminary findings from these studies suggest a positive impact on students' interest and their overall grasp of mathematical concepts. Visual arts, in this context, serve as a conduit for students to perceive the creative dimensions of mathematics, transforming their outlook from one of mundanity to that of intrigue and exploration.

Against this backdrop, a comprehensive literature review on the impact of integrating visual arts to bolster students' interest in mathematics assumes paramount importance. This review endeavors to scrutinize various studies within this domain, dissect their key findings, and provide a nuanced understanding of how visual arts can be judiciously employed in mathematics education. Furthermore, it aims to delineate the success factors associated with visual arts integration and pinpoint challenges demanding attention in the implementation of this pedagogical approach.

The research problem at the core of this paper revolves around the quest to enhance students' interest and engagement in mathematics, a subject often met with less favor and correlated with low academic achievement. In addressing this challenge, the study delves into innovative strategies geared towards revitalizing students' interest and engagement in the realm of mathematics. Therefore, the main contribution of this paper is the Systematic Literature Mapping (SLM) showing the research direction, particularly associating visual arts that can be done to address this challenge. In broad terms, the Research Question (RQ) is defined as follows: "How can visual arts be implemented in mathematics education to enhance students' interest and engagement?"

Therefore, this research aims to contribute to the development of teaching strategies that can help stimulate students' interest in mathematics, making this subject more appealing and fostering students' curiosity in exploring mathematical concepts. The purpose of this study is to provide an overview of the role of the arts in increasing students' interest, understanding, and involvement in learning mathematics at various levels of education.

Related Works

Recently, there's been a lot of buzz among researchers and educators about weaving visual arts into the fabric of math education. A bunch of studies has dived into how mixing visual arts into the math scene affects students' interest and grasp of the subject. According to (Sharp et al., 2018), students who get involved in activities that blend art and learning feel the positive vibes. Their research indicates a strong correlation between the integration of art, especially visual arts, and the development of geometric reasoning and scientific observation skills. On the other hand, there are also several studies indicating challenges in implementing visual arts in the context of mathematics education. One such study conducted by (Daugherty, 2008) explores the potential of visualization software in mathematics education but identifies factors such as cost, complexity, and lack of flexibility as hindrances to widespread adoption.

Furthermore, there are also studies conducted to compare the effectiveness of visual arts integration with other learning approaches. (Woolner, 2004, 2006) compared visual and verbal teaching approaches and found that classes taught verbally scored much higher in mathematical competence. No interaction was found between teaching style and student preference, although visualizers tended to perform less well.

Method and Materials

This study was conducted using a literature review approach to collect, analyze, and synthesize previous research relevant to the integration of visual arts in mathematics learning. In broad terms, this research was carried out in the following steps:

(1) Identifying the sources of literature data to be used. These data sources can include scientific articles, books, theses, dissertations, and other relevant publications. In this article, the data sources used are scientific articles published in reputable international journals or proceedings published within the last 10-16 years to ensure relevance to current trends.
(2) Keywords Selection. The chosen keywords are "visual art" and ("mathematics education" or "Math Learning"). Utilizing these keywords to conduct searches in relevant databases.
(3) (3) Conducting a literature search using the specified keywords in the academic databases of Cambridge (https://www.cambridge.org/universitypress), Science@Direct (http://www.sciencedirect.com/), Springer Link (http://link.springer.com/), and Taylor and Francis (https://www.tandfonline.com/). Reviewing abstracts and article titles found to determine their relevance to the research topic. Subsequently, a strict selection is carried out based on predetermined inclusion and exclusion criteria. Inclusion criteria may include relevance to the integration of visual arts in mathematics education and publication in English.
(4) Collecting data from relevant literature sources that have been approved.
(5) Analyzing the collected data to identify the main findings of previous research. Synthesizing these findings to develop a deeper understanding of the impact of integrating visual arts in enhancing students' interest in mathematics.
(6) Compiling the literature review report following the predetermined structure, including the introduction, literature review, methodology, results and discussion, conclusion, and bibliography.

The method that is used in this paper is described as follows.

Searching Strategy

To guarantee that the data for this study is gathered from the most pertinent and current sources, a thorough and methodical search for pertinent literature was done. The search strategy involves the following steps:

(1) Keyword Determination. In this stage, the identification of keywords relevant to the research topic is conducted. The main keywords used include "visual art" and ("mathematics education" or "Math Learning").

(2) Database Search. In this stage, the identified keywords are searched in several academic databases. These databases are Cambridge (https://www.cambridge.org/universitypress), Science@Direct (http://www.sciencedirect.com/), Springer Link (http://link.springer.com/), and Taylor and Francis (https://www.tandfonline.com/).

(3) Limited Date Search. The search scope is confined to literature published in the last 10-16 years. This limitation is strategically imposed to guarantee alignment with contemporary advancements in the amalgamation of visual arts within the domain of mathematics education.

(4) Employing Boolean Operators. This study used Boolean operators such as "AND" and "OR" to combine keywords in the searches conducted.

(5) Initial Selection. During this phase, an examination of the abstracts and titles of articles derived from the preliminary search outcomes is undertaken to ascertain their pertinence to the research subject. Subsequently, articles deemed relevant are compiled into a roster for subsequent in-depth evaluation.

(6) Evaluation of Inclusion Criteria. The chosen articles are subsequently appraised against the established inclusion criteria. These criteria encompass alignment with the integration of visual arts in mathematics education and publication in the English language.

(7) Bibliography and Cross-Referencing. Furthermore, an examination of the references in pertinent articles and cross-referencing is undertaken to identify supplementary literature that might not have been accounted for in the initial search.

This search strategy is crafted to guarantee the comprehensiveness and relevance of the gathered literature, aiming to foster a profound understanding of the implications of integrating visual arts into mathematics education. The amassed data serves as the foundational material for the subsequent analysis and synthesis in this literature review.

Research Questions

In seeking to explore how the incorporation of visual arts into mathematics learning influences students' interest in the subject, this literature review aims to tackle the following Research Questions (RQ):

(1) What positive impact does integrating visual arts into mathematics learning have on students' interest?
This inquiry serves as the cornerstone for the literature review, directing the identification and scrutiny of empirical evidence that substantiates the favorable effects of employing visual arts to augment students' interest in mathematics. This encompasses enhancements in motivation, comprehension, and the way students perceive the subject.

(2) What factors contribute to and hinder the integration of visual arts into mathematics learning?
This question seeks to uncover elements that can either facilitate or impede the successful integration of visual arts into mathematics education. It encompasses the role of educators, available resources, and various factors influencing the implementation process.

(3) What are the effective learning models and methodologies for incorporating visual arts into mathematics learning?

This question focuses on identifying learning models or approaches that have proven effective in integrating visual arts into mathematics teaching. This includes projects in mathematical art, the use of mathematical aesthetics concepts, and other successful methods.

(4) How does the integration of visual arts in mathematics learning compare to other approaches in terms of enhancing student interest?

This question allows for a comparison between the effectiveness of integrating visual arts with other learning approaches in mathematics. It aids in understanding the relative strengths or weaknesses of using visual arts in mathematics education.

The research questions aim to guide and structure this literature review, assisting in identifying the main findings to be presented in this paper. These questions are also aligned with Additional research questions as indicated in Table 1.

Table 1. Additional Research Questions

ID	Research Question
RQ 1	What Art Can Be Used In Learning Mathematics
RQ 2	How Art Can Increase Students' Interest In Learning Mathematics
RQ 3	How Art Can Increase Student Engagement In Learning Mathematics
RQ 4	How Art Can Improve Students' Understanding In Learning Mathematics
RQ 5	What Are Examples Of Art In Learning Mathematics

From these research questions, the PICOC method (Population Intervention Comparison Outcome Context) (Petticrew & Roberts, 2008) is then employed to define the scope and terms used in the search string, as illustrated in Table 2.

Table 2. PICOC

PICOC	Description
Population (P)	the role of art in learning mathematics
Intervention (I)	Not Applicable
Comparison (C)	learning mathematics in a classic way
Outcome (O)	the benefits of learning with art
Context (C)	Not Applicable

The next step is to determine keywords and search strings. The keywords used are shown in table 3. The search strings used are "visual art" and ("mathematics education" or "Math Learning"). Based on this string, a total of 2,486 articles were obtained from the range 1837-2023. The results obtained are the results before filtering. After filtration, 193 articles were obtained that met the criteria. Inclusion and exclusion criteria will be explained in the next subsection.

Table 3. Keywords

Keyword	Related to
art in mathematics	Population
classical leaning mathematics	Population
learning mathematics in a classic way	Comparison
the benefits of learning with art	Outcome
the role of art in learning mathematics	Population

Inclusion and Exclusion Criteria

As mentioned in the previous section, the obtained documents consist of 2,486 articles collected from the specified sources at the beginning. Therefore, the next step is to establish inclusion and exclusion criteria to select only relevant articles for use. Subsequently, these criteria are applied to eliminate articles that are not related to the research objectives. Parsifal is used to support this mapping. In selecting literature for this review, several inclusion and exclusion criteria have been applied to ensure the selection of relevant and quality studies. These criteria serve as guidelines in the literature selection process.

Table 4. Inclusion and Exclusion Criteria

Inclusion Criteria	Description
1	Search by title and abstract
2	Studies published between 2019 – 2023
3	Studies from Q1, Q2, Q3 and Q4 SJR
4	Studies we have full access to using the university credentials
Exclusion Criteria	**Description**
1	Non Related Study
2	Non-Accessible Complete Article
3	Proceeding Article
4	Published Before 2019
5	SR or SLR Article
6	Non English Paper

Inclusion criteria are as follows:

(1) Relevance to Visual Arts Integration in Mathematics Learning. Articles or research to be included in this literature review must be clearly related to the use of visual arts in the context of mathematics learning. These articles should discuss or examine the impact of visual arts integration on students' interest in mathematics.

(2) Articles or research included must be written in English. This criterion is applied to ensure accurate understanding of the presented material.

(3) Limited Time Range. Literature included in this literature review must be published within the last 10-16 years. This is done to ensure that the literature review encompasses recent works relevant to the latest

developments in the integration of visual arts in mathematics education.

The exclusion criteria applied are as follows:

(1) Not Relevant to the Research Topic. Articles or studies that are not directly relevant to the integration of visual arts in mathematics education or do not discuss the influence of visual arts on students' interest in mathematics will be excluded from the literature review.

(2) Languages Other Than English. Literature written in languages other than English will be excluded from the literature review to ensure accurate understanding.

(3) Non-Indexed Publications. Sources not published in officially indexed scientific journals will be excluded. This was done to ensure the quality of the research included in the literature review.

(4) Full Text Not Available. Articles or research that do not have access to the full text or cannot be easily accessed will be excluded.

These inclusion and exclusion criteria have been applied to ensure that the literature included in the literature review is the most relevant and of good quality in the context of this study. This also helps in maintaining the precision and focus of this literature review.

Quality Assessment

Based on the guidelines provided by (Kitchenham, 2012), researchers can develop a quality assessment for the foundational studies. Quality assessment is a crucial step in conducting this literature review to ensure that the literature included in the analysis is reliable and relevant research. Out of the 193 articles obtained after applying the inclusion and exclusion criteria, a reevaluation was conducted using the Assessment Questions. These questions were formulated in a table based on the work of (Neiva et al., 2016; Steinmacher et al., 2013)

Table 5. Assessment Question (AQ)

Assessment Question	Description
AQ1	Is the research's purpose clearly stated?
AQ2	Does the researcher propose or develop solutions or strategies?
AQ3	Does the researcher evaluate the solutions or strategies they propose?
AQ4	Is the data collection process clearly described?
AQ5	Is the data analysis method explained, such as the statistical tests used in quantitative research, and so forth?
AQ6	Are the research objectives or questions answered?
AQ7	Does the researcher mention the limitations of the study?
AQ8	Does the researcher provide guidance for further research?

For each question, the following scores are assigned: 1 for "Yes," 0.5 for "Partially," and 0 for "No." The following factors are used to measure the quality of research:

(1) Research Methodology. Each study considered in this literature review was assessed based on the research methodology used. Research that uses a strong research design, such as field experiments, case studies, or strong qualitative research, gets higher marks in terms of methodology.

(2) Sample and Population. Research quality is also assessed based on the representation of the sample and population used in the research. Research that uses a representative sample of the student population or learners has a better assessment.

(3) Statistical Analysis. Research that utilizes appropriate and relevant statistical analysis to answer research questions gets better ratings in terms of data analysis.

(4) Controlling factors. Another criterion for evaluation is how successfully variables that could affect research outcomes were controlled. Higher scores for internal validity are given to research that takes these factors into account and controls them.

(5) Publication and Reputation. The journal or publication in which the research was published was also assessed. Research published in leading journals in the fields of education, arts, or mathematics scores higher in terms of reputation.

Quality assessment was carried out objectively and systematically to ensure that only high-quality studies were included in the analysis of this literature review.

Results

Based on the initial search results by applying the predefined strings, out of 2486 documented publications from Taylor and Francis, Springer Link, Science@Direct, and Cambridge, the distribution is shown in the figure below. To determine the eligibility of the studies, all publications that utilized social media as identified sources were considered, based on the definition provided in (Ghermandi & Sinclair, 2019).

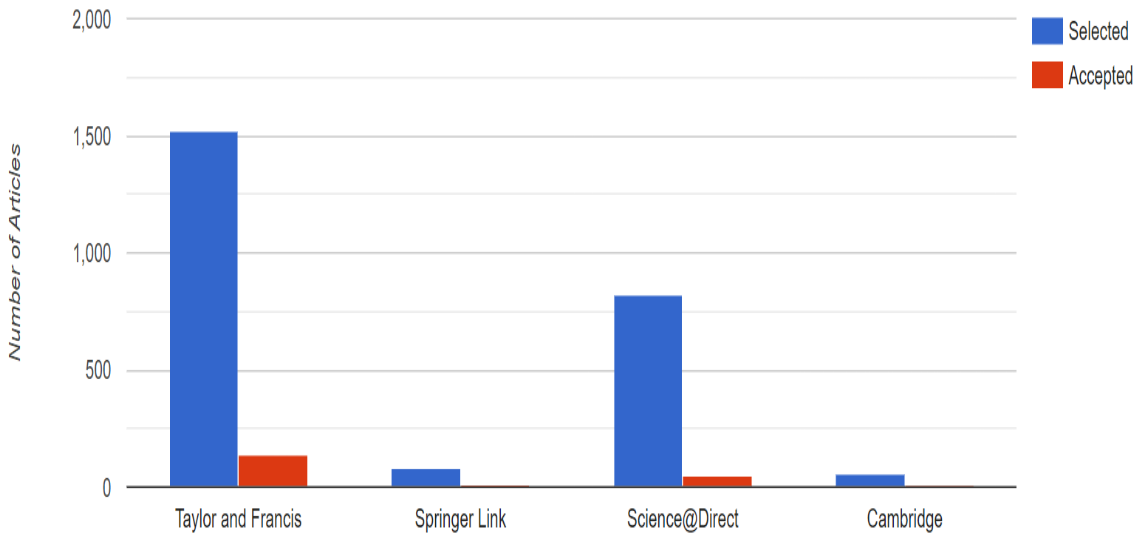

Figure 1. Distribution of Publisher

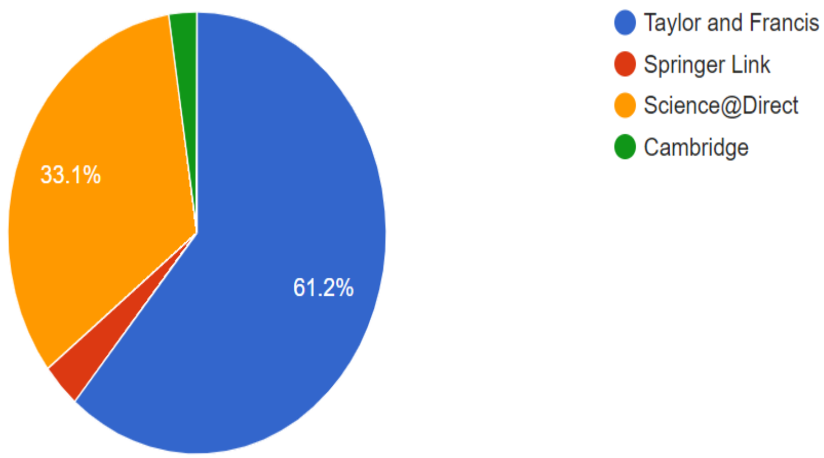

Figure 2. Percentage of the Distribution of Publisher

Then, after applying the inclusion criteria (First level), 193 relevant articles were obtained. Furthermore, after conducting the quality assessment, 45 suitable articles were identified. Figure 3 displays changes in the volume of papers produced from 2007 to 2023. There was a sharp decline in the number of articles that published between 2007 and 2008. Interestingly, even though the period from 2020 to 2022 was during the COVID-19 pandemic, article publications experienced an increase.

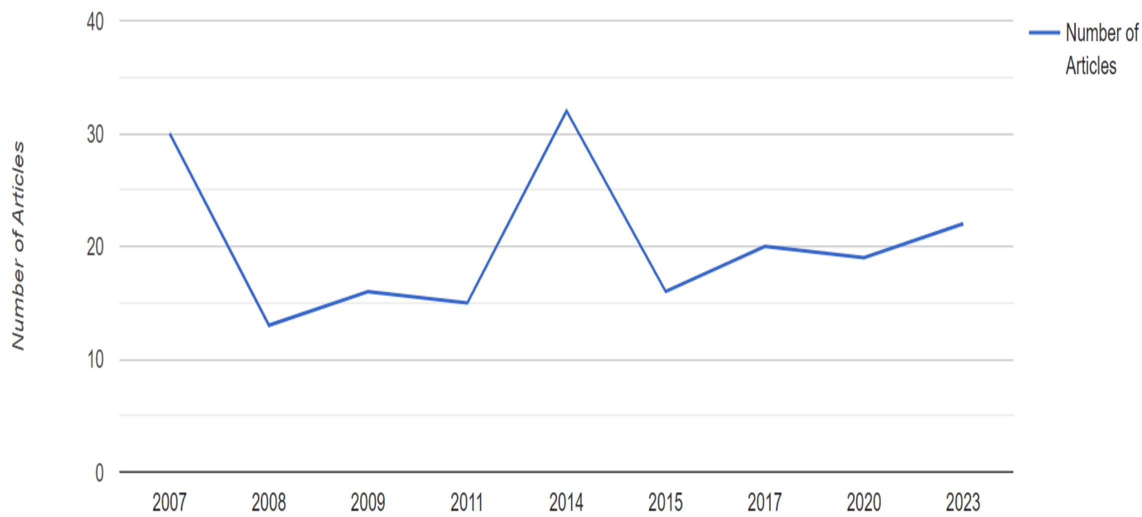

Figure 3. Graph Showing the Increase in the Volume of Articles Published

To dive into the latest research trends, we dug into the nitty-gritty details. We used a tool called VOS Viewer, a nifty little tool that paints a clear picture of how different keywords, topics, and research articles are connected. The graph below paints the results of our analysis. In this graph, you'll spot various keywords, each one represented by differently colored and sized dots. These dots aren't just there for decoration; they actually tell us something. The size of a dot indicates how closely linked it is to the research topics, and dots of the same color hang out in the same research neighborhood. For example, there's a purple clique that includes keywords like "arts," "learning," "classroom," and "students." Then there's the brown bunch with "mathematics," "arts," and "geometry." Finally, we have the cool blue crew featuring keywords like "Symmetry," "computer," and "art."

These clusters help us get a better grip on what's cooking in the world of research.

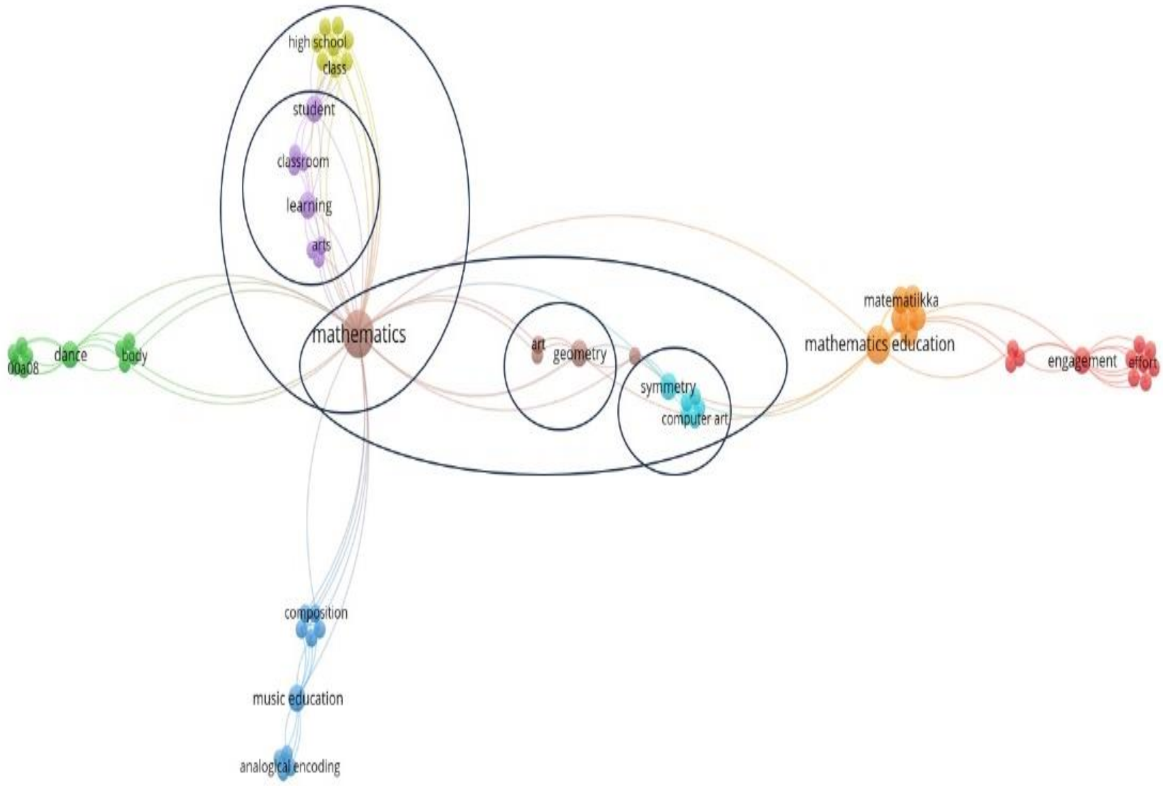

Figure 4. Graph Showing the Increase in the Volume of Articles Published

As mentioned earlier, the initial article search yielded 2,486 results at the primary stage (utilizing specified strings in the retrieved database). Subsequently, following a rigorous research selection process involving exclusion and inclusion criteria, 193 articles were identified. Further undergoing quality assessment, only 45 articles met the criteria. This process is elucidated in the subsequent PRISMA diagram (see Figure 5).

Data Extraction

The literature review process commenced with the identification of relevant studies through a meticulous search across various academic databases and digital libraries. Keywords employed in the search encompassed "visual arts," "mathematics," "student interest," and other related keyword variations. Following the initial search, studies meeting the inclusion and exclusion criteria were identified to be included in this literature review. As mentioned in the previous section, the obtained documents consist of 2,486 articles collected from the specified sources.

RQ 1. What art can be used in learning mathematics?

Based on the results of a literature review of selected papers, information was obtained indicating that various types of art can be used in mathematics learning. Specifically, in terms of dance, (Gerofsky, 2013) explores the work of a modern dancer who incorporates number theory into her dance, highlighting the potential for embodied mathematical engagement. (Wood, 2008) describes the use of dance and movement to engage students in mathematical investigations, showing that it can deepen understanding and motivate learning. (Kremling et al., 2018) reflects on the potential of dance as a pathway to experiencing mathematics and highlights its emancipatory potential. Several other related studies include (Mui, 2010; Thomas & Peebles, 2016).

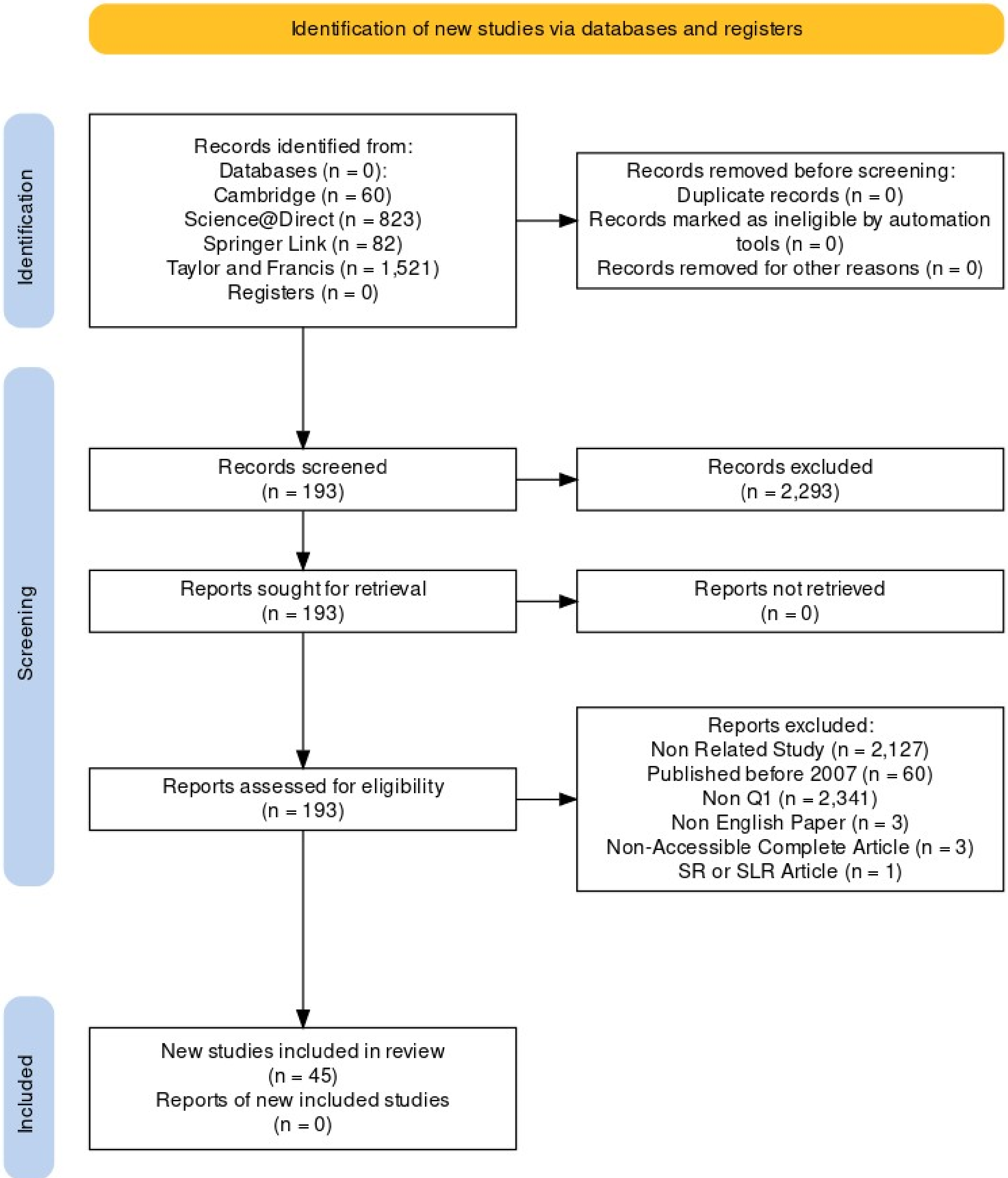

Figure 5. PRISMA Diagram

In visual arts, some of these are done by(Bekene Bedada & Machaba, 2022; Campbell, 2017; Edens & Potter, 2007; Harriss & Segerman, 2022; Karaali & Uehara, 2020; Kurtuluş & Uygan, 2010; Sears et al., 2019; Sparavigna & Baldi, 2017) . (Nutov, 2021) found that integrating art into the curriculum increased motivation, positive feelings, and curiosity among pre-service teachers, and was positively correlated with achievements in mathematical tasks. Roberts 2019 highlighted the importance of visualizations in teaching and learning mathematics, including the use of 3D models and software tools.

The use of music in mathematics learning as shown by (Hamilton et al., 2019) reports on a pilot study that uses music and musical rhythm to teach mathematics, specifically fractions, equivalence, ordinance, and division. Preliminary data suggest that students are responding positively to this teaching methodology. (Jones & Dunn Pearson, 2013) describes lessons integrating music and math in elementary school, where students learn music theory and apply it to create their own musical phrases. These findings indicate that learning mathematics with music can enhance student engagement and understanding. Other aspects of art that is used in mathematics learning also studied by (Sancar-Tokmak & Incikabi, 2013; Shmukler & Ziskin, 2014).

RQ 2. How art can increase students' interest in learning mathematics?

(Kristof et al., 2016) described that Visual illusions are an exciting pedagogical opportunity for raising students' interest towards mathematics and natural sciences and technical aspects of visual arts. using experiential education of mathematics through arts and playful activities to raise students' interest towards mathematics and natural sciences and technical aspects of visual arts.

(Ernest & Nemirovsky, 2013) explores connections undergraduate students found between mathematics and their own lives, as realized through mathematically inspired art projects. Engaging in mathematically inspired art projects in the mathematics classroom can encourage students to make meaningful connections between mathematics and their personal lives. (Higashio et al., 2017) studied the relationship between interest and learning. Interest is closely associated with learning as it allows improving and complementing the introduction of an object, to guide meaningful learning, to improve their long-term memory as well as a source of knowledge and orientation of motivation for further learning. It greatly affects motivation and cognitive activity of students. Students tend to engage themselves in deeper learning on a particular subject when they have an interest.

RQ 3. How art can increase student engagement in learning mathematics?

(Kristof et al., 2016) focusing on using experiential education of mathematics through arts and playful activities to raise students' interest towards mathematics and natural sciences and technical aspects of visual arts. (Beermann, 2018)examine the effects of art integration on students' dispositions, students' enjoyment of mathematics, and students' academic achievement in the core content area of mathematics.(Barana & Marchisio, 2020) focused on the importance of engagement in Mathematics education and how it can be supported to enhance learning outcomes, especially for students with challenging backgrounds. (Franke et al., 2015)analyze the level at which students engaged with each other's mathematical ideas and the moves teachers used to support student engagementPlease embed

RQ 4. How art can improve students' understanding in learning mathematics?

The papers collectively suggest that art can contribute to students' understanding in learning mathematics. (Yadav,

2019) found that integrating art and technology in mathematics education helped students understand mathematical concepts and improve their performance. (Tramonti & Paneva-Marinova, 2019) presented a learning and teaching approach that combined art and technology to stimulate and motivate secondary school students in mathematics, helping them recognize the mathematical basis of art. Overall, these papers suggest that incorporating art into mathematics education can enhance students' understanding of mathematical concepts.

(Moerman, 2020)Paying careful attention to art and math adequate language in "meta talks" with children about their art work is found to be a rich tool in enhancing the young learner's development of aesthetic, numeric and linguistic literacies in gainful interplay. The main idea of the paper is to present a practical work model and an educational theory discussion on the status and potential of art work in teaching and learning math in early childhood education. The central idea is to let the child’s free creative art activity reveal, or “teach”, whatever mathematical thinking was inherent in the creative process. The paper also discusses the importance of paying careful attention to art and math adequate language in “meta talks” with children about their art work, which is found to be a rich tool in enhancing the young learner’s development of aesthetic, numeric and linguistic literacies in gainful interplay. (Ward, 2014) has main idea to using art to teach math concepts.

RQ 5. What are examples of art in learning mathematics

These papers collectively suggest that art can be used as a tool to teach mathematics and enhance students' understanding and interest in the subject. (Séquin, 2005) discusses how art can be used to introduce mathematical concepts and spark students' curiosity. (Shukla, 2019) focusing to provide strategies to teach mathematics, especially to gifted students, and to instill a love of mathematics in them. The paper emphasizes the importance of showing students the beauty and elegance of mathematics, and providing opportunities for them to experience the joy of solving difficult problems and understanding deep concepts. The paper also discusses the use of computer programming, storytelling, puzzles, and creative problem solving to make learning interesting for students. The emotional and psychological aspects of mathematical cognition and learning are also taken into account

Data Analysis

Data extracted from the studies included in this literature review was then thematically analyzed. The data analysis process involved the following steps:

(1) Grouping Findings: Key findings from the analyzed studies were grouped based on specific themes or topics, such as "positive effects," "supporting factors," "challenges," and "effective learning models."
(2) Comparison and Contrast: These findings were then compared and contrasted to identify common patterns in the analyzed literature. This included comparing positive outcomes and constraints identified in the use of visual arts in mathematics learning.
(3) Presentation of Findings: The findings discovered through the data analysis were systematically presented in the "Results and Discussion" section to support the key findings in this literature review.

The aim of this data analysis process is to elucidate empirical evidence supporting the positive effects of visual arts integration in mathematics learning and to identify critical issues that need attention in the implementation of this approach in an educational context. Some of the things that were obtained include:

(1) Positive Influence of Visual Arts Integration on Students' Interest in Mathematics. The findings of this literature review clearly indicate a positive influence of visual arts integration in mathematics learning on students' interest. Consistently, the analyzed studies report increased student interest in mathematics when visual arts are used as a learning tool. Visual arts provide students with the opportunity to interact with mathematical concepts creatively, transforming their negative perceptions of mathematics into something interesting and relevant.

(2) Supporting Factors and Challenges in Visual Arts Integration. While there is ample positive evidence regarding the influence of visual arts in mathematics learning, this literature review also identifies several supporting factors and challenges that need attention. Supporting factors include the role of teachers skilled in integrating visual arts, the development of relevant visual arts materials, and support from the education system.

(3) On the other hand, some challenges in implementing this approach include resource limitations, both in terms of visual arts materials and teacher training. Additionally, negative perceptions of teachers and students towards mathematics, as well as reluctance to adopt new approaches, are constraints that need to be overcome.

(4) Effective Learning Models and Methodologies. This literature review also reveals that some learning models and methodologies have proven effective in incorporating visual arts into mathematics learning. These models include mathematical art projects, the application of mathematical aesthetics concepts, and the use of visual arts as a tool to explore mathematical concepts.

(5) Comparison with Other Approaches. This literature review also compares the effectiveness of visual arts integration with other learning approaches in mathematics. The results indicate that visual arts often create higher interest compared to more traditional approaches. However, further research is needed to understand these differences more deeply.

Threats to Validity

In the process of conducting this literature review, it is crucial to address various threats to validity that can impact the interpretation of findings and the generalizability of results. The following are key threats to validity that warrant acknowledgment:

Threats to Internal Validity

(1) Selection Bias: There is a potential for bias in the selection of studies incorporated into the literature review. To mitigate this concern, rigorous inclusion and exclusion criteria were implemented, ensuring the inclusion of only pertinent and high-quality studies.

(2) Construct Threat: The possibility of variations in the measurement of specific variables across different studies. Steps have been taken to identify and elucidate these differences in research outcomes.

Threats to External Validity

Generalizability of Results. There is a possibility that the findings in this literature review may have limitations in generalizability. These limitations could arise from variations in educational contexts, student populations, or teaching methods. The authors make an effort to identify and present the specific context of each analyzed study.

Threats to Conclusion Validity

(1) There are limitations in the available data in the literature, categorized as data limitations. Extracted data is restricted to what has been reported in the analyzed studies.
(2) Another potential concern is research selection bias within the analyzed literature. To mitigate this, efforts have been made to seek studies with strong and relevant research methods.

The authors have diligently tackled these challenges by implementing a systematic and unbiased approach to data selection and analysis. However, it's crucial to recognize that literature reviews inherently come with limitations related to generalizability and variations in research methods and contexts. Consequently, the outcomes of this literature review should be interpreted with a mindful consideration of these constraints.

Research Directions

The insights from this literature review propose potential avenues for further research, stemming from the outcomes of the review:

(1) Development of Integrated Learning Models: Future research endeavors could concentrate on crafting more intricate and cohesive learning models that seamlessly integrate visual arts into the mathematics curriculum.
(2) Long-Term Evaluation: Conducting studies with longitudinal approaches presents an opportunity to comprehend the enduring impact of visual arts integration on students' interest in mathematics. Such investigations can ascertain whether the interest cultivated by this approach can endure over an extended duration.
(3) Effects on Specific Student Groups: Further research initiatives can delve into whether visual arts integration elicits distinct effects on particular student demographics, such as students with special needs or those from diverse cultural backgrounds. This exploration aids in identifying the most inclusive approaches to mathematics education.
(4) Development of Visual Arts Materials: Research efforts can be concentrated on formulating more precise and pertinent visual arts materials tailored for specific mathematical concepts. This involves creating artworks explicitly designed to facilitate the comprehension of intricate mathematical principles.
(5) Teacher Training: Delving into studies on teacher training programs that focus on integrating visual arts into mathematics education can offer valuable insights into preparing educators to adeptly adopt this approach.
(6) Measurement of Creativity: Further research can consider how visual arts integration enhances students' creativity in mathematics and how this creativity can be measured and assessed.

(7) Comparison with Other Approaches: Broader comparative studies can be conducted to gain a deeper understanding of the effectiveness of the visual arts integration approach compared to other learning approaches in mathematics.

Conclusion

This exploration of literature underscores how incorporating visual arts significantly enhances students' fascination with mathematics. Bringing visual arts into math learning not only sparks students' curiosity but also fuels their motivation, transforming the way they perceive this subject from intimidating to engaging and relevant. A crucial insight gleaned is that visual arts empower students to creatively delve into mathematical concepts. When students express mathematical ideas through visual arts, it encourages them to think more abstractly and critically, establishing a connection between mathematical abstraction and practical, real-world applications.

Equally important is acknowledging the pivotal role of teachers in seamlessly integrating visual arts into mathematics education. Educators proficient in this approach become catalysts for heightened interest in mathematics among students, guiding them to explore visual arts as a tool for comprehending mathematical concepts. However, navigating challenges is inevitable in the implementation of visual arts integration in math education, encompassing resource constraints and the perceptions of both teachers and students. Consequently, this approach necessitates robust support from the education system, targeted teacher training, and the creation of pertinent visual arts materials. Understanding the positive potential of merging visual arts with math learning and addressing prevailing challenges paves the way for crafting more effective and inclusive teaching methodologies. This not only cultivates students' interest in mathematics but also stimulates their creative thinking while deepening their grasp of mathematical concepts. To sum up, delving into the integration of visual arts into mathematics education reveals a promising avenue for research, promising substantial impacts on students' interest and comprehension of mathematics. Continuing research in this direction and adopting best teaching practices can illuminate pathways to a richer understanding and heightened enthusiasm for the realm of mathematics.

Acknowledgements

This study was funded by Hibah Penulisan Artikel Review Universitas Padjadjaran grant number 1549/UN6.3.1/PT.00/2023.

References

An Bhaird, C. Mac, Fitzmaurice, O., Nífhloinn, E., & O'sullivan, C. (2013). Student non-engagement with mathematics learning supports. *Teaching Mathematics and Its Applications*, *32*(4), 191–205. https://doi.org/10.1093/TEAMAT/HRT018

Barana, A., & Marchisio, M. (2020). An interactive learning environment to empower engagement in

Mathematics. *Interaction Design and Architecture(s)*, *45*, 302–321. https://doi.org/10.55612/S-5002-045-014

Beermann, A. A. (2018). *Art integration , mathematics , and behavior*.

Bekene Bedada, T., & Machaba, F. (2022). The effect of GeoGebra on STEM students learning trigonometric functions. *Cogent Education*, *9*(1). https://doi.org/10.1080/2331186X.2022.2034240

Campbell, J. M. (2017). Visualizing large-order groups with computer-generated Cayley tables. *Journal of Mathematics and the Arts*, *11*(2), 67–99. https://doi.org/10.1080/17513472.2017.1318511

Daugherty, S. C. (2008). *A Study of Visualization for Mathematics Education*.

Edens, K., & Potter, E. (2007). The Relationship of Drawing and Mathematical Problem Solving: Draw for Math Tasks . *Studies in Art Education*, *48*(3), 282–298. https://doi.org/10.1080/00393541.2007.11650106

Ernest, J. B., & Nemirovsky, R. (2013). Creating Art as a Catalyst for Making Meaningful, Personal Connections to Mathematics. In *Proceedings of Bridges 2013: Mathematics, Music, Art, Architecture, Culture*. https://doi.org/ISBN 978-1-938664-07-6

Franke, M. L., Turrou, A. C., Webb, N. M., Ing, M., Wong, J., Shin, N., & Fernandez, C. (2015). Student Engagement with Others' Mathematical Ideas. *Https://Doi.Org/10.1086/683174*, *116*(1), 126–148. https://doi.org/10.1086/683174

Ganal, N. N., & Guiab, M. R. (2014). PROBLEMS AND DIFFICULTIES ENCOUNTERED BY STUDENTS TOWARDS MASTERING LEARNING COMPETENCIES IN MATHEMATICS. *International Refereed Research Journal ■www.Researchersworld.Com■Vol.-V*, *4*. www.researchersworld.com

Gerofsky, S. (2013). *Learning Mathematics Through Dance*.

Ghermandi, A., & Sinclair, M. (2019). Passive crowdsourcing of social media in environmental research: A systematic map. *Global Environmental Change*, *55*, 36–47. https://doi.org/10.1016/J.GLOENVCHA.2019.02.003

Hamilton, T. J., Doai, J., Milne, A., Saisanas, V., Calilhanna, A., Hilton, C., Goldwater, M., & Cohn, R. (2019). Teaching Mathematics with Music: A Pilot Study. *Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018*, 927–931. https://doi.org/10.1109/TALE.2018.8615262

Harriss, E., & Segerman, H. (2022). The art of illustrating mathematics. In *Journal of Mathematics and the Arts* (Vol. 16, Issues 1–2, pp. 1–10). Taylor and Francis Ltd. https://doi.org/10.1080/17513472.2022.2085977

Higashio, S., Kuchner, M. J., Silverberg, S. M., Azmidar, A., Darhim, D., & Dahlan, J. A. (2017). Enhancing Students' Interest through Mathematics Learning. *Journal of Physics: Conference Series*, *895*(1), 012072. https://doi.org/10.1088/1742-6596/895/1/012072

Jones, S. M., & Dunn Pearson, J. (2013). Music. *Http://Dx.Doi.Org/10.1177/1048371313486478*, 698–720. https://doi.org/10.1177/1048371313486478

Karaali, G., & Uehara, S. (2020). Beauty Beyond Perfection: Aesthetic Values in Japanese Art Resonant with Mathematics. *Proceedings of Bridges 2020: Mathematics, Art, Music, Architecture, Education, Culture*, 467–470.

Kitchenham, B. A. (2012). *Systematic review in software engineering*. 1–2. https://doi.org/10.1145/2372233.2372235

Kremling, J., Arndt, N., Roman, A., Zilm, M., & Straehler-Pohl, H. (2018). Dancing on the junction of mathematics and bodily experience. *The Mathematics Enthusiast*, *15*(1), 201–227. https://doi.org/10.54870/1551-3440.1424

Kristof, ;, Koskimaa, R. ;, Lavicza, Z., Fenyvesi, K., Koskimaa, R., & Lavicza, Z. (2016). Experiential Education of Mathematics: Art and Games for Digital Natives. *Kasvatus Ja Aika*, *9*(1), 107–134. https://jyx.jyu.fi/handle/123456789/50754

Kurtuluş, A., & Uygan, C. (2010). The effects of Google SketchUp based geometry activities and projects on spatial visualization ability of student mathematics teachers. *Procedia - Social and Behavioral Sciences*, *9*, 384–389. https://doi.org/10.1016/j.sbspro.2010.12.169

Moerman, P. (2020). Letting Art Teach Aesthetics, Math and Language. *The Bridges 2020 Conference on Mathematics, Art, Music, Architecture, Education*. https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1462499&dswid=-4161

Mui, W. L. (2010). Connections between contra dancing and mathematics. *Journal of Mathematics and the Arts*, *4*(1), 13–20. https://doi.org/10.1080/17513470903188182

Neiva, F. W., David, J. M. N., Braga, R., & Campos, F. (2016). Towards pragmatic interoperability to support collaboration: A systematic review and mapping of the literature. *Information and Software Technology*, *72*, 137–150. https://doi.org/10.1016/J.INFSOF.2015.12.013

Nutov, L. (2021). Integrating visual arts into the mathematics curriculum: The case of pre-service teachers. *Teaching and Teacher Education*, *97*, 103218. https://doi.org/10.1016/J.TATE.2020.103218

Ogochukwu, N. V. (2010). Enhancing students interest in mathematics via multimedia presentation. *African Journal of Mathematics and Computer Science Research*, *3*(7), 107–113. http://www.academicjournals.org/AJMCSR

Petticrew, M., & Roberts, H. (2008). Systematic Reviews in the Social Sciences: A Practical Guide. *Systematic Reviews in the Social Sciences: A Practical Guide*, 1–336. https://doi.org/10.1002/9780470754887

Sancar-Tokmak, H., & Incikabi, L. (2013). The effect of expertise-based training on the quality of digital stories created to teach mathematics to young children. *Educational Media International*, *50*(4), 325–340.

Sears, R., Hopf, F., Torres-Ayala, A., Williams, C., & Skryzpek, L. L. (2019). Using Plan-Do-Study-Act Cycles and Interdisciplinary Conversations to Transform Introductory Mathematics Courses. *PRIMUS*, *29*(8), 881–902. https://doi.org/10.1080/10511970.2018.1532938

Séquin, C. H. (2005). Looking At Math: Using Art to Teach Mathematics. In *Renaissance Banff: Mathematics, Music, Art, Culture. Southwestern College, Winfield, Kansas: Bridges Conference* (Issue Section 2).

Sharp, L. A., Tiegs, A., Coneway, B., Hindman, J. T., Garcia, B., & Bingham, T. (2018). Window On a Wider World (WOWW): A new advocate for learning through the arts among rural elementary schools. *Childhood Education*, *94*(5), 23–33. https://doi.org/10.1080/00094056.2018.1516469

Shmukler, A., & Ziskin, C. (2014). Through the looking glass of history: Mathematicians in the land of poetry. *Journal of Mathematics and the Arts*, *8*(1–2), 78–86. https://doi.org/10.1080/17513472.2014.930229

Shukla, A. (2019). On teaching mathematics to gifted students: some enrichment ideas and educational activities. *ArXiv: History and Overview*.

Sparavigna, A. C., & Baldi, M. M. (2017). Symmetry and the golden ratio in the analysis of a regular pentagon. In *International Journal of Mathematical Education in Science and Technology* (Vol. 48, Issue 2, pp. 306–316). Taylor and Francis Ltd. https://doi.org/10.1080/0020739X.2016.1233587

Steinmacher, I., Chaves, A. P., & Gerosa, M. A. (2013). Awareness support in distributed software development: A systematic review and mapping of the literature. *Computer Supported Cooperative Work*, *22*(2–3), 113–158. https://doi.org/10.1007/S10606-012-9164-4/TABLES/9

Sullivan, P., Tobias, S., & McDonough, A. (2006). Perhaps the decision of some students not to engage in learning mathematics in school is deliberate. *Educational Studies in Mathematics*, *62*(1), 81–99. https://doi.org/10.1007/S10649-006-1348-8/METRICS

Thomas, M., & Peebles, C. (2016). A Graph-Theoretic Approach to the Analysis of Contra Dances. In *Proceedings of Bridges 2016: Mathematics, Music, Art, Architecture, Education, Culture*.

Tramonti, M., & Paneva-Marinova, D. I. (2019). Maths, art and technology: A combination for an effective study. *TEM Journal*, *8*(1), 82–86. https://doi.org/10.18421/TEM81-11

Ward, R. (2014). Go Figure! Using the Art of Jasper Johns to Teach Number Concepts. *Dimensions of Early Childhood*, *42*(2), 23–27. http://www.moma.org/collection/artist.php?artist_id=2923

Wood, K. (2008). Mathematics through Movement: An Investigation of the Links between Kinaesthetic and Conceptual Learning. *Australian Primary Mathematics Classroom*.

Woolner, P. (2004). A comparison of a visual-spatial approach and a verbal approach to teaching mathematics. *International Group for the Psychology of Mathematics Education*.

Woolner, P. (2006). Teaching and Learning Mathematics Visually or Verbally: A Comparison of Two Teaching Approaches and Investigation of Interactions With Pupil Cognitive Style. *Journal of Cognitive Education and Psychology*, *5*(3), 288–309. https://doi.org/10.1891/194589506787382459

Yadav, S. (2019). How art contribute to the understanding of mathematical concepts? *International Journal of Research and Analytical Reviews (IJRAR)*, *6*(4), 291-294.

Author Information

Sisilia Sylviani
https://orcid.org/0000-0002-7480-7742
Universitas Padjadjaran
Jl. Ir. Soekarno Km. 21, Jatinangor, Sumedang
Indonesia
Contact e-mail: *sisilia.sylviani@unpad.ac.id*

Fahmi Candra Permana
https://orcid.org/0000-0001-6231-840X
Universitas Pendidikan Indonesia
Jl. Pendidikan No.15, Cibiru Wetan, Kec. Cileunyi
Kabupaten Bandung, Jawa Barat 40625
Indonesia

Ahamad Tarmizi Azizan
https://orcid.org/0000-0003-4361-147X
Faculty of Creative Technology and Heritage
University of Kelantan Malaysia
Pengkalan Chepa, 16100 Kota Bharu,
Kelantan.
Malaysia