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A Bibliometric Analysis of Mathematical Mindset and Scale Comparison

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Abstract
This study aims to identify articles that have the most significant influence on the topic of mathematical mindset and comparison of scale types. The types of scales that are focused on in this research included Likert, Thurstone, and Semantic Differential. This research method uses a literature review with bibliometric analysis techniques. The software used is Publish or Perish by Harzings and VOSviewer. The search was carried out several times using various index sources, such as Google Scholar, Scopus, and Crossref, from 2013 to 2025. A total of 1,254 articles were identified with the keywords "mathematical mindset", "Thurstone", "Likert", "differential semantic", and "scale". The results show that Boaler et al.'s article occupies the top position in search results and the Likert scale is the most commonly used scale in a mathematical mindset.
Keywords: math mindset, mindset, scale comparison

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INTRODUCTION

The necessity for developing a mathematical mindset has become a focus of increasing interest in the discipline of mathematics' education in the twenty-first century (Pyper, 2015). A mathematical mindset not only aids students in mastering mathematical concepts but also in solving difficulties in everyday life and in professional situations (Boaler, 2016; Dweck, 2022; Moore, 2018).

This research used bibliometric analysis as a technique for examining the rate of development of publications related to the mathematical mindset. Tomaszewski (2023) defines bibliometrics as an interdisciplinary research field that is employed by practically all scientific areas. Meanwhile, Ariyani et al. (2022) and Ersozlu & Karakus (2019) define bibliometric analysis as a research strategy that analyzes bibliographic data and scientific publications to find trends, patterns, and impacts of research in a certain field of study. Bibliometric analysis is also a common and comprehensive way of examining and comprehending vast amounts of scientific data (Donthu et al., 2021).

Bibliometric analysis in the context of a mathematical mindset can give significant insights into how instruments are used to measure it and what sorts of scales have been utilized and produced in the scientific literature. Bibliometric analysis is made a simpler with the use of VOSviewer software (Muhammad et al., 2022; van Eck & Waltman, 2020). This can help researchers identify study possibilities such as state-of-the-art, novelty, and acceptable research gaps for future research.

This article compares different types of scale and discusses the importance of having a mathematical mindset. It is widely known that non-cognitive test research often uses the Likert scale due to its ease of use in term of preparation, answering, and data processing (Roberts et al., 1999; Setiawati, 2013; Tanujaya et al., 2022). However, there are other types of scales available, such as Thurstone, Semantic Differential, and others.

The purpose of this study is to evaluate bibliometrically the trend of publications that raise the subject of mathematical thinking in terms of scale selection. Thus, non-cognitive test researchers can investigate whether the form of scale can be utilized to gauge a person's attitude.

Mathematics: Overview

The mathematical mindset consists of up of two concepts: mathematics and mindset. Mathematics is a science that can be studied and mastered by everyone (NCTM, 2000). Mathematics and other scientific lessons have been the emphasis of education for many parties throughout the world (Akbasli et al., 2016). Mathematics has an important part in many aspects of life (Peterman & Ewing, 2019). Mathematics is one of the most significant mental tools that humans have (Daly et al., 2019).

Boaler (2016) and many other experts agree that nature, art, and the world are all brimming with mathematics. As the Queen of Science (Morus, 2013), mathematics is in almost all branches of science. If students find understanding mathematics is challenging and think that mathematics is a pure theoretical science, it is then their educators need to introduce that mathematics is a beautiful science and can be applied in real life. Everyone needs math not just for work and school, but in our everyday lives (Petherbridge, 2020). Petherbridge (2020) also said that mathematics is the ability to recognize patterns which range from fractals in river deltas, lightning bolts, blood vessels, and tree branches to the rotational symmetry of flowers and beyond. Mathematics is a way that the Creator provided so these humans can understand the world around them. Besides that, everything humans do cannot be separated from mathematics (Lucini & Boltz, 2023).

Mindset Theory

Hoeve et al. (2019) explained that mathematics is a very important subject where mindset plays a big role. Meanwhile, mindset is closely related to mental health symptoms (Zhu et al., 2022). Mindset refers to individuals' implicit ideas on essential human qualities (Ronkainen et al., 2019). Jeffs, et al. (2021) explain more simply, that mindset is a person's confidence in their ability as either fixed or growth. Meanwhile, Ingebrigtsen (2018) explains that a mindset is just a belief that is not often conveyed verbally. Mindset or thought patterns are abstract nouns that cannot be touched but whose presence can be felt. Ingebrigtsen (2018) also extracted the word mindset from search results, one of which was mindset refers to the cognitively active processes that occur in connection to a certain activity. This is in line with what Wesneski (2019) said that individuals' attitudes toward these circumstances might be classified as either fixed or growth mindsets. Mindset is not an inanimate object that has remained since humans were born. Mindset can change and develop as human efforts are made to train it (Dweck, 2022).

Research on the brain strengthens the theory that the human brain is malleable and can be filled with various experiences (Chen et al., 2021). They also explained that a person's mindset depends on a person's strategy and performance in absorbing something. Mindset greatly influences how a person responds to talent, intelligence, and what character he or she wants to have (Sembiring, 2017). Sembiring also explained that mindset is so important in human life because mindset is also part of determining progress and potential development. Moore (2018) in his research explained that implicit theories of intelligence or mindset is important factors that can help someone understand the intelligence and motivation of teenagers, especially in mathematics' lessons.

Mathematical Mindset

Some people still have a strong belief those mathematics is a subject that can only be mastered by someone with 'natural' mathematical abilities (Moore, 2018). This belief confirms that people who do not have the ability will not be able to master it (Mosley, 2017; Murphy & Thomas, 2008). Moore (2018) in her research wrote that some experts also believe that math genius is frequently associated with innate talent and masculinity. Mathematics is often considered a male-only subject. The stereotype that women are not suitable in the world of arithmetic results in a view that belittles women's abilities (Dweck, 2008). Especially if women and marginalized people have to try hard to understand mathematics, then this effort is considered proof as they do not have 'natural' abilities. This was later refuted by several researchers. The more difficult a lesson is, the more stimulated the brain will be to think and add new neuron networks (Boaler, 2016; Dweck, 2008).

Dweck (2008) states that mindset can predict students' math and science achievement over time. This confirms that a person's mathematical ability can develop (Boaler, 2013). Anyone can become a math person or an expert in mathematics (Petherbridge, 2020). However, some believe that talent and intelligence are needed to be able to master mathematics.

Saefudin, et al. (2023) explained that mathematical mindset is an implicit explanation of the flexibility and stability of human qualities connected to mathematical ability, intellect, and skill. Daly, et al. (2019) explained that mathematical mindset is based on two assumptions of mathematical intelligence. The first assumption is that someone has a fixed mind and thinks that mathematical abilities are inherited (genetically inherited intelligence). Meanwhile, the second assumption is someone who thought that mathematical abilities can be improved by doing exercises. The second assumption is called a 'growth mathematics mindset. Students who believe that mathematical intelligence can be improved will tend to have higher mathematics scores. On the other hand, students who believed that math intelligence could not be changed had their math scores decrease. A mathematical mindset also correlates with academic grit (Kaya & Karakoc, 2022). Although several studies have found that mindset does not affect learning outcomes. However, it needs to be understood that changing your mindset from fixed to growth requires a long process. As well as how mindset can influence a person's attitude. Thus, seeing the results of a growth mindset cannot be seen instantly. Boaler, et al. (2021) explain that the willingness to face challenges and struggle is an important key to instilling a growth mathematical mindset.

Scale Type: Thurstone, Likert, and Semantic Differential

The Thurstone Scale was developed in 1920 by American psychologist Louis Leon Thurstone. Thurstone's scale is known as "The Law of Comparative Judgment" (Thurstone, 1994). Test participants are allowed to provide more flexible responses regarding the statements submitted (Bahar et al., 2021). Thurstone allows test takers to choose more answers than a Likert scale (Drasgow et al., 2010). Likert (1932) said that Thurstone put all his efforts into measuring psychological aspects that were previously considered difficult to measure. Thurstone created a continuum scale from 1 to 11 to produce interval data so that even though each item has a different number of scores, the distance between the items is the same (Arfandi et al., 2020).

The Likert scale was developed by Rensis Likert which aims to complement the shortcomings of the attitudes measurement scale previously developed by Thurstone. Over time, the Likert scale has become the type of scale most often used in research (Joshi et al.,

2015), including in qualitative research (Tanujaya et al., 2022). Initially, the Likert scale was created to make it easier for test takers to indicate the level of agreement (from strongly disagree to strongly agree) through statement items given in the form of a metric scale (Joshi et al., 2015). Joshi, et al. also explained that in its development, there were not only five types of Likert scales but also 7 and 11 types of scales. Scales with seven answer choices provide more types of choices which in turn increase the probability of meeting the test taker's objective reality (Joshi et al., 2015).

Besides Thurstone and Likert, there is also a Semantic Differential scale that can be used as an alternative non-cognitive test. The Semantic Differential scale was developed by Osgood (1964) who defined it as "a set of concepts against a set of adjectival scales". It involves a series of 7-point scales with two polar opposite adjectives, such as good and bad (Heise, 1970; Norman, 1959). Heise (1970) also explained that there are three dimensions to differential semantics: Evaluation, Potency, and Activity.

Research Question

Based on the introduction and theoretical framework above, this study aims to answer Research Questions (RQ):

RQ1. What articles have the most scientific impact from 2013 to 2025?

RQ2. What type of scale is most widely used in mathematical mindset research and comparison of scales based on the output of VOSviewer?

METHODS

Research Design

This research uses a research design in the form of a literature reviews. A literature review is not just collecting articles from various journals but a great technique to aggregate study findings to establish evidence at the meta-level and to identify areas that require more investigation, which is a crucial component of developing a theoretical framework and conceptual model (Snyder, 2019). The type of literature review used in this research is bibliometric analysis.

Subject of the Study

This research did not use people as research subjects but various articles from journals indexed by Google Scholar, Scopus, and Crossref. The search range starts from 2013 to 2025. Based on the results of several searches, were found 1,254 articles referring to the mathematical mindset, Thurstone, Likert, Semantic Differential, and scale.

Data Collection

The articles that have been collected are then stored in the form of a ris/ref manager and then entered into VOSviewer. The device will output three kinds of maps (van Eck & Waltman, 2010). The three maps provide an overview of the network, overlay, and density visualization. Network visualization explains how close and related keywords are to other words. Overlay visualization explains how old or new an article is discussing related keywords and other items. Finally, the density visualization explains how much research has been done on keywords and other items. The steps for searching the article can be seen in Figure 1.

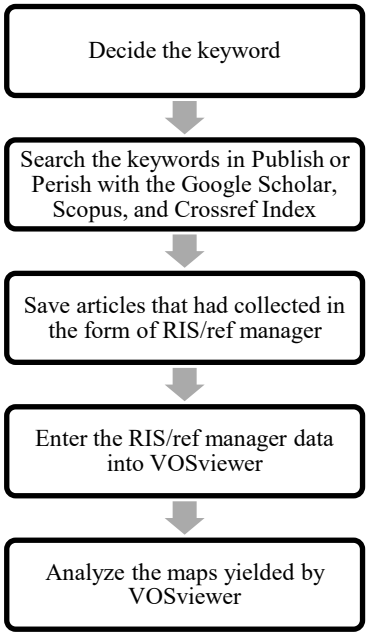

Figure 1. Research Steps

RESULTS & DISCUSSION

Results

The article's scientific impact analysis is to answer RQ1 of this research. Articles that have been found using Publish or Perish are sorted by several citations. The number of citations shows the scientific impact of the writing on the world of research or its usefulness in society. The high or low scientific impact of an article in a scientific journal can be measured by high the frequency of references or references to the writings contained in a journal (Devos, 2011). Scientific impact can be seen from journal profiles on Google Scholar and other indexers that have metrics or calculations (Aulianto et al., 2020). Table 1 is a list of the top 8 articles based on Publish or Perish with the keyword "mathematical mindset".

Based on search results, the article Boaler, et.al. (2021) topped the rankings. Boaler has indeed written a lot and introduced the concept of a mathematical mindset. Boaler et al.'s (2021) article, "The transformative impact of a mathematical mindset experience taught at scale," tops the list with the highest number of citations (65). It indicates that the article is highly influential and a primary reference in research on the topic of mathematical mindset. The second most highly cited article is by Boaler, Brown & LaMar (2022) with 55 citations, demonstrating that the work of Boaler and other collaborators consistently dominates this field.

The titles in the table indicate a variety of research focuses, ranging from broad-scale mindset experiences, the effects of short-term interventions, the development of mathematical mindset scales, student mindset characteristics, the relationship between mindset and mathematical imagination, and critiques of the mindset concept itself. This diversity illustrates that the study of mathematical mindset is not only descriptive but also

develops towards measurement, attitude evaluation, learning innovation, and critical analysis of concepts applied in mathematics education.

Table 1. Top 8 Scientific Impact Articles of Mathematical Mindset

No.	Authors/ Researchers	Title	Publication Year	Publisher	DOI or ISBN	Cites [a]
1	Jo Boaler, Jack A. Dieckmann, Tanya LaMar, Miriam Leshin, Megan Selbach-Allen and Graciela Pérez-Núñez	The transformative impact of a mathematical mindset experience taught at scale	2021	Frontiers in Education	https://doi.org/10.3389/feduc.2021.784393	65
2	J Boaler, K Brown, T LaMar	Infusing mindset through mathematical problem solving and collaboration: Studying the impact of a short college intervention	2022	Education mdpi.com	https://doi.org/10.3390/educsci12100694	55
3	Seongah Im, Hye-Jin Park	A mathematical mindset scale using the positive norms	2023	Psychology in the School, Wiley	https://doi.org/10.1002/pits.22904	14
4	Abdul Aziz Saefudin, Ariyadi Wijaya, Siti Irene Astuti Dwiningrum, Djohan Yoga	The characteristics of the mathematical mindset of junior high school students	2022	Eurasia Journal of Mathematics, Science and Technology Education	https://doi.org/10.29333/ejmste/12770	13
5	Panayiota Irakleous, Constantinos Christou, & Demetra Pitta-Pantazi	Mathematical imagination, knowledge and mindset	2021	ZDM-Mathematics Education, Springer	https://doi.org/10.1007/s11858-021-01311-9	11
6	JD Diaz	Inheriting the historical limits of inclusion: when Making a mathematical mindset is not enough	2021	Philosophy of Mathematics Education Journal, EBSCO	1465-2978	8
7	Anita L. Campbell, Mashudu Mokhithib, and Jonathan P. Shock	Exploring mathematical mindset in question design: Boaler's taxonomy applied to university mathematics	2021	REES AAEE	9781925627718	4
8	M Durrani	A mathematical mindset	2018	IOP – Physics World	10.1088/2058-7058/32/12/32	0

[a]Based on Google Scholar Index

Source: Publish or Perish, 2025

Discussion

Three outputs from VOSviewer explain the constellation of the dots that represent keywords. The first output is a network visualization that provides an overview of the relationship between the main keyword and other keywords. According to van Eck and Waltman (2020)in the network visualization display, VOSviewer provides an output image in the form of a circle that represents a keyword. The bigger the label and the circle of an item, the greater its weight. In addition, VOSviewer categorizes items into clusters. Between clusters are distinguished by different colors. The closer a circle is to another circle, the stronger the relatedness of each item, and vice versa.

In the overlay visualization display (Fig. 2), it can be seen that the mathematical mindset has the largest circle compared to other items. It can also be seen that the

mathematical mindset has a relationship with the Likert scale. However, for Thurstone, it seems far away and not even directly related. Meanwhile, there is no visible differential semantic scale. This shows that research related to mathematical mindset uses more Likert scales than Thurstone, and almost none uses semantic differential scales.

Research related to mindset and mathematical mindset uses a Likert scale with a different number of choices. Some researchers use a 5-point response Likert scale (Balan & Sjöwall, 2022; Chen et al., 2021; Cho et al., 2021; Garofalo, 2016; Wang et al., 2021; Wesneski, 2019; Zhao et al., 2018). Several researchers used the Implicit Theories of Intelligence Scale (ITIS) instrument developed by Dweck with a 1-6 Likert scale (Apiola & Sutinen, 2020; Hoeve et al., 2019; Magnus Ingebrigtsen, 2018; Kaya & Karakoc, 2022; Lottero-Perdue & Lachapelle, 2019; Meierdirk & Fleischer, 2022; Park, 2021; Ronkainen et al., 2019; Shoshani, 2021). There are also researchers who use a 4-point Likert scale (Moore, 2018).

Figure 2 also shows that the mathematical mindset generally uses a Likert scale which is also close to Confirmatory Factor Analysis, evaluation, psychometric properties, and validation. Meanwhile, the circle that shows Thurstone seems to stand alone and is not adjacent to other items, except web items.

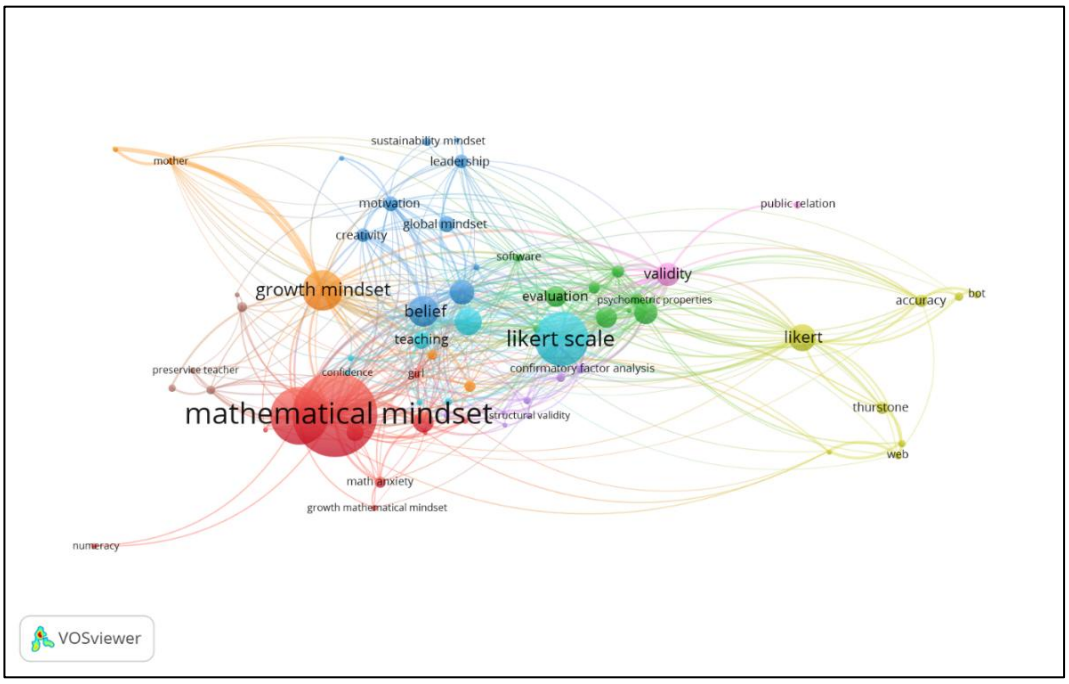

Figure 2. Network Visualization of Mathematical Mindset with Scale Comparison

The second output from VOSviewer is the overlay visualization shows the latest research in terms of the year it was published (Fig. 3). In Figure 3 it appears that VOSviewer distinguishes items from yellow to dark blue. The yellow items in Figure 3 indicate that these items are classified as newly studied. On the other hand, items that are dark blue indicate an earlier year of publication. The longest year in Figure 3 is 2019 indicates that the topic of mathematical mindset can still be an interesting topic for research. Meanwhile, the items colored yellow in Figure 3 are shown by some of the items such as mother, public relations, and bot. Researchers interested in deepening the mathematical mindset can choose these three items as research objects.

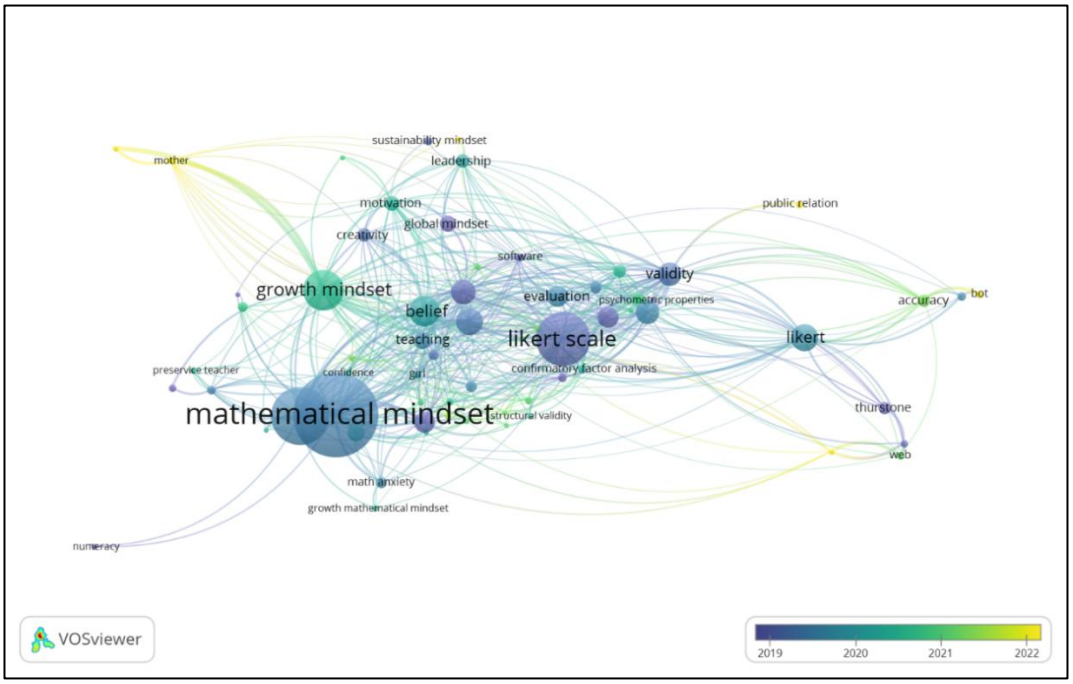

Figure 3. Overlay Visualization of Mathematical Mindset with Scale Comparison

The last ouput is density visualization (Fig. 4) provides an overview of how much publication is based on the item in the map. The brighter the circle on an item, the more researchers have published it. Darker and fainter, indicating that the item is rarely studied. The default color given by VOSviewer to indicate thickness is in the range of blue to green to yellow (van Eck & Waltman, 2020).

The density visualization shows that the mathematical mindset topic has the largest and brightest circles compared to other items. The Likert scale is also brighter than the Thurstone. In this display, it can also be seen that the Thurstone is fainter than the Likert scale. This means that there are more publications about mathematical mindset and Likert scales than other items that are as brightly colored as these two items.

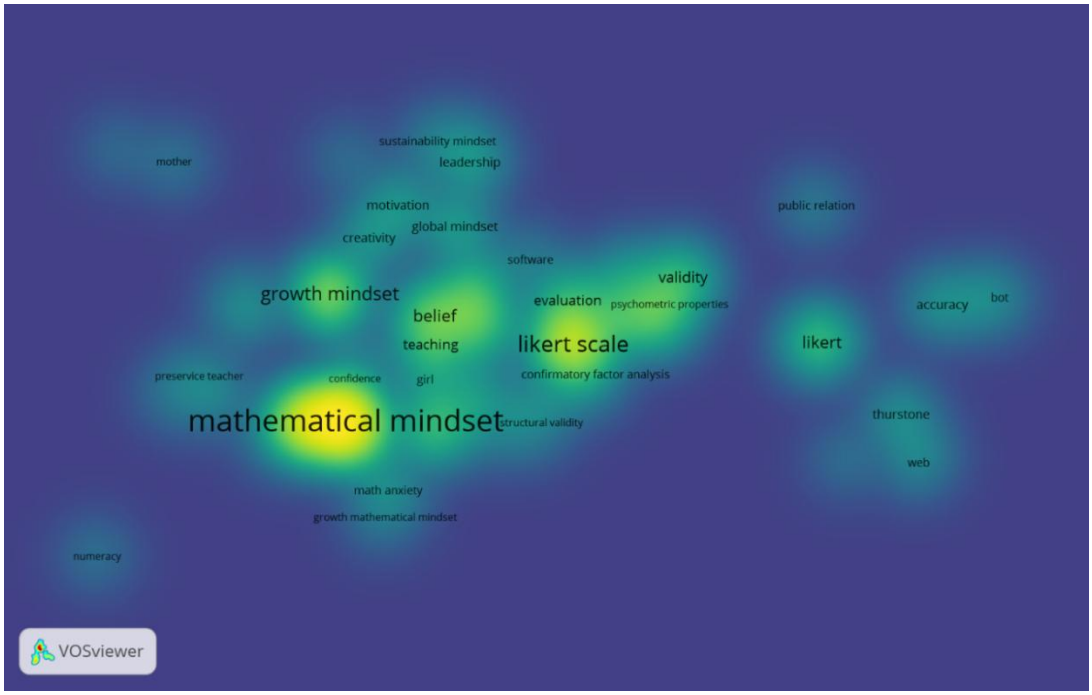

Figure 4. Density Visualization of Mathematical Mindset with Scale Comparison

When the keywords were focused on scale, it looks like in Figure 5. In the overlay visualization display, there are 6 clusters. Cluster 1 consists of confirmatory factor analysis, evaluation, exploratory factor analysis, factor structure, Likert data, Likert format, Likert type scale, psychometric properties, psychometric property, response category, Rosenberg self-esteem scale, scale, semantic differential scale, validation, and validity. Cluster 2 consists of accuracy, comparison, data system, instrument, Likert, Likert type, psychometric characteristic, scale method, score, sensitivity, and Thurstone. Cluster 3 consists of interval, item, Likert item, Likert scale, Likert type data, ordinal scale, test, type data, and type item. Cluster 4 consists of assessment, measurement, parameter, rating, rating scale, response, and scale length. Cluster 5 consists of correlation, experiment, model, questionnaire, SPSS, stability, and survey. Cluster 6 consists of factor analysis, KR20, Likert scale data, and reliability.

Figure 5 shows that the Likert scale has the biggest circle compared to Thurstone and Semantic Differential. Thurstone's distance to the scale item is furthest. Meanwhile, the distance between the Likert scale and semantic differential is relatively close. The Thurstone scale is not widely used by researchers because the preparation procedure takes a long time and is too laborious (Barclay & Weaver, 1962; Edwards & Kenney, 1946). Effendi (1989) explained that an instrument using the Thurstone scale must be validated by 50 to 100 experts who understand the variable to be measured. Unfortunately, the scale that has been successfully prepared can change over time, so it must be reviewed periodically.

Likert is the scale that is preferred by researchers (Garofalo, 2016; Tanujaya et al., 2022). However, this scale can produce data with social desirability bias. Some respondents will choose the "neutral" or undecided" option and refuse to choose an extreme answer (strongly disagree or strongly agree). They were afraid the answer would not be socially acceptable (Garland, 1991). Dweck (1999) also developed a mindset instrument with four

scale types and some provided six scale types. Both types of mindset tests do not have undecided, neutral, or undecided options.

Osgood then tried to cover Likert's shortcomings with a Differential Semantic scale (Widhiarso, 2010). This scale allows respondents to provide choices according to their feelings, not just agree or disagree. Research conducted by Friborg (2006) also shows that semantic differential can reduce agreement bias while psychometric quality still good.

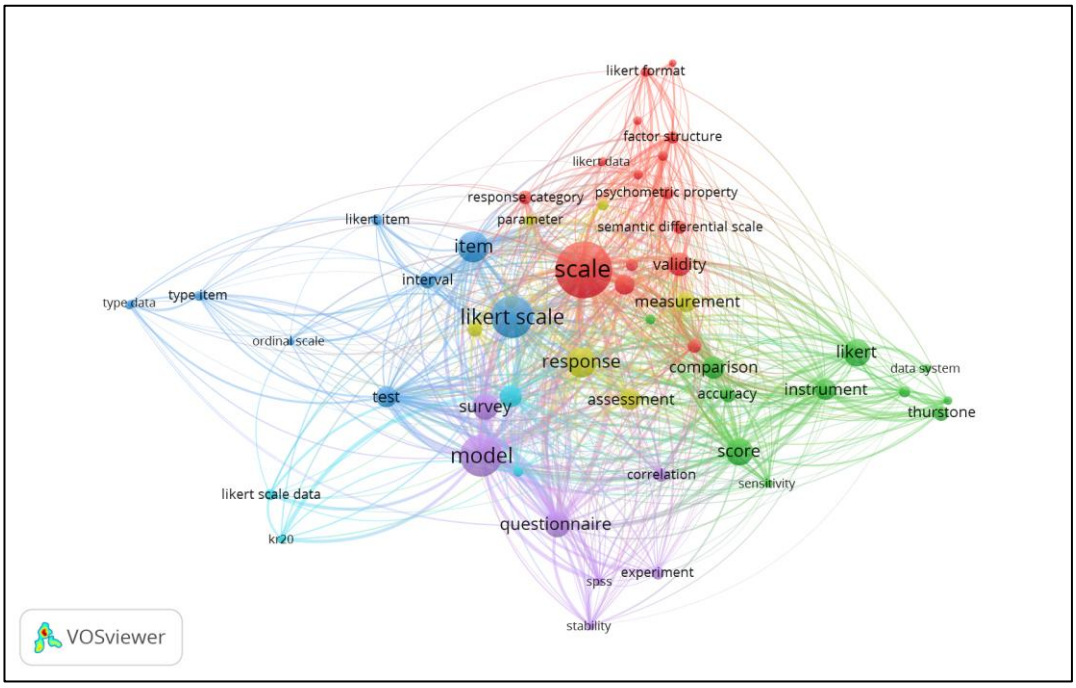

Figure 5. Network Visualization of Scale Comparison

CONCLUSION

This research aims to answer RQ1 and RQ2. In RQ1, based on search results with Publish or Perish, it was found that the article that had the most impact on the topic of mathematical mindset was an article by Boaler, et al. The article titled "The transformative impact of a mathematical mindset experience taught at scale" was published in 2021 and has been cited 65 times. The article of Boaler, et al. still has a higher number of citations per year.

In RQ 2, based on VOSviewer result, it was found that the Likert scale is more numerous than the Thurstone scale and Semantic Differential. Thus, research related to mathematical mindset by using the Thurstone scale, semantic differential, SJT, or other types of scales can be a good research opportunity in the future, especially in measuring tool development research. Research related to mathematical mindset is important to find an effective way to measure mindset and its influence on student academic achievement.

However, this research has limitations that could lead to opportunities for further investigation. One of these is that the search to scale types only focused on Likert, Thurstone, and Differential Semantics. Recently, several new type of non-cognitive test has developed, such as the Situational Judgment Test (SJT) or others. In addition, this study only used one software to search for relationships between items. Meanwhile, there are much other softwares that can be used to strengthen this research. Finally, because this

research is a review literature, further research is needed, especially on the topic of mathematical mindset and scale development.

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