ISSN 2502-5872 (Print)
ISSN 2622-3627 (Elektronik)

Volume 8 Number 2, May 2023, 405-422

REFRACTIVE THINKING IN SOLVING MATHEMATICAL PROBLEMS IN INDONESIA: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Refractive thinking is a thinking process that produces decisions through critical and reflective thinking. Refractive thinking focuses on critical thinking and problem-solving abilities. Both of these abilities are essential abilities in the 21st century that are needed by students. Research on refractive thinking in solving math problems has started to become a concern in the last 10 years. This study aims to describe the results of studies related to refractive thinking in solving math problems in Indonesia. This study used a Systematic Literature Review (SLR) method with a quantitative approach, involving 17 published studies as a sample which were filtered through inclusion criteria. This study took the stages of data collection, data analysis, and conclusions drawing. The results show that the research on refractive thinking in solving mathematical problems in Indonesia has been viewed from several aspects, most of these research show that students meet the indicators of refractive thinking on the component of identifying problems, and some of them show that students have not met the indicators on the strategy and evaluation components, and the use of Peer-Assisted Reflection learning models can improve mathematical refractive thinking abilities. Many of these studies involved junior high school students as participants because mathematical abilities begin to be honed at that level. In addition, the type of research most widely used is qualitative because this approach provides an in-depth understanding of refractive thinking in solving mathematical problems.
Keywords: Math Problems, Refractive Thinking, Systematic Literature Review

How to Cite: Septian, T & Juandi, D. (2023). Refractive Thinking in Solving Mathematical Problems in Indonesia: A Systematic Literature Review. *Mathline: Jurnal Matematika dan Pendidikan Matematika, 8*(2), 405-422. http://doi.org/10.31943/mathline.v8i2.398

PRELIMINARY

Education in the 21st century requires students to have essential skills so they can solve problems in an increasingly complex life (Kemendikbud, 2019). Based on this, the Partnership for 21st Century Learning (2019) developed a learning framework for the 21st century that describes the combination of skills, knowledge, literacy, and expertise that must be mastered by students. In the learning framework, the essential skills that students must learn and master are mentioned. Some of them are critical thinking and problem-

solving abilities (Kemendikbud, 2019; P21, 2019). Both abilities are the focus of refractive thinking (Pagano & Roselle, 2009).

Refractive thinking is a thought process that produces decisions through reflective and critical thinking (Maslukha et al., 2018; Prayitno, 2016). The occurrence of refractive thinking through reflective and critical thinking makes refractive thinking part of higher-order thinking skills. This is in line with the opinion of King et al. (1998) who state that critical and reflective thinking are part of higher-order thinking skills. The refractive thinking process occurs when students face complex problems that can make them reflect on their experience and knowledge, then they will critically analyze things obtained from the results of reflection by evaluating the information gradually, thus allowing students to choose alternative solutions that will lead to a decision (Prayitno et al., 2014; Sari et al., 2022). Thus, refractive thinking can be interpreted as a critical analysis of the information obtained from reflective thinking to get a decision.

The refractive thinking process consists of four stages as proposed by Prayitno (2016), namely perplexity, investigation, constructive activity, and evaluation. Perplexity and investigation are stages in reflective thinking, while constructive activity and evaluation are stages in critical thinking. Prayitno et al. (2014) also stated the components of refractive thinking which are consisting of the identification of problems, strategy, and evaluation. These components can be used to measure students' refractive thinking ability.

Refractive thinking needs to be mastered by students because it can help them in constructing knowledge. According to Pagano dan Roselle (2009), the knowledge development cycle consists of three stages, namely reflection, critical thinking, and refraction. In addition, refractive thinking focuses on critical thinking and problem-solving ability (Pagano & Roselle, 2009). Critical thinking abilities are needed for students to develop problem-solving abilities (Prayitno, 2015), while problem-solving abilities can help students make a decision (Putri & Juandi, 2022).

Refractive thinking also needs to be learned by students because it is part of higher-order thinking skills. According to Riadi and Retnawati (2014), higher-order thinking skills are needed by students to be able to create solutions to problems in life that are complex, unstructured, complicated, and non-routine. In addition, higher-order thinking skills can help them to have a successful careers in the future (Alismail & McGuire, 2015). Thus, refractive thinking is important for students to learn.

Research on refractive thinking has started to become a concern for researchers over the past decade, especially in the mathematics field since Prayitno et al. (2014)

constructed the components of refractive thinking. Several studies related to refractive thinking in solving mathematical problems have been conducted, especially in Indonesia (Fatoni et al., 2021; Maslukha et al., 2018; Nurlan et al., 2023; Prayitno et al., 2014; Sari et al., 2022a; Sumarno et al., 2017; Yenti et al., 2020). The findings in these studies are very diverse and some of them may be find biased results. To obtain comprehensive information related to refractive thinking in solving mathematical problems, a literature review is needed. Therefore, this study will systematically review the literature related to refractive thinking in solving mathematical problems using the Systematic Literature Review (SLR) method. The main purpose of this study is to describe the results of research related to refractive thinking in solving mathematical problems in Indonesia. Specifically, the description will be carried out based on the year of publication, publication media, research demographics, education level of the sample or research subject, type of research, and research results.

METHODS

This research used the Systematic Literature Review (SLR) method with a quantitative approach. SLR is a way to synthesize scientific evidence to answer certain research questions comprehensively (Lame, 2019; Littell et al., 2008). The data in this study are secondary data in the form of primary research results on refractive thinking in solving mathematical problems.

This research follows the SLR research stages proposed by Juandi (2021), namely data collection, data analysis, and conclusion drawing. Data were collected through databases registered by Google Scholar, Garuda, and Repository. Data collection was also done through a search on Publish or Perish to find the number of articles related to the topic discussed. Based on the search results, 25 published studies related to refractive thinking in solving mathematical problems were found, including the refractive thinking process, refractive thinking ability, and construction of refractive thinking components.

After the data was collected, all articles found were extracted and only articles that met the inclusion criteria were selected for analysis (Juandi, 2021). The inclusion criteria in this study are as follows:

1. Research in the form of journal articles, proceedings, and final college assignments (final project, theses, and dissertations).
2. Research is the result of mathematics learning results.
3. The research is conducted in Indonesia.

4. The research period is from 2014 to 2023.
5. The research discusses refractive thinking in solving mathematical problems.
6. Research published in Repository and indexed journals (Sinta, Scopus, and Garuda).
7. Contains the type of research (quantitative, qualitative, and mixed-method).
8. The research sample or subjects consisted of elementary to university students.

Based on the predetermined inclusion criteria, 17 published studies were selected as samples. These articles will be analyzed in this study.

RESULT AND DISCUSSION

The results of data analysis in this study are the results of analysis of the research on refractive thinking in solving mathematical problems. By applying the inclusion criteria for all relevant studies found, the studies were categorized based on the year of publication, publication media, research demographics, education level of research participants, and type of research. The presentation of results of the analysis of 17 research samples based on the categories mentioned is presented in Table 1.

Table 1. Sample Data Analysis Results

Category	Variations	Quantity
Years of Publication	2014 – 2016	0
	2017	1
	2018	3
	2019	3
	2020	2
	2021	4
	2022	3
	2023	1
Publication Media	Scopus Journals	3
	Sinta Journals	4
	Garuda Journal	1
	Repository	8
Research Demographics	Sumatera	3
	Jawa	12
	Kalimantan	0
	Sulawesi	2
	Papua	0
Education Level of Research Participants	Elementary School	1
	Junior High School	8
	Senior High School	4
	Higher Education	4
Type of Research	Quantitative	2
	Qualitative	14
	Mixed-methods	1

Studies Based on Year of Publication

The number of studies on refractive thinking in solving mathematical problems in 2014 to 2023 is presented in the following figure.

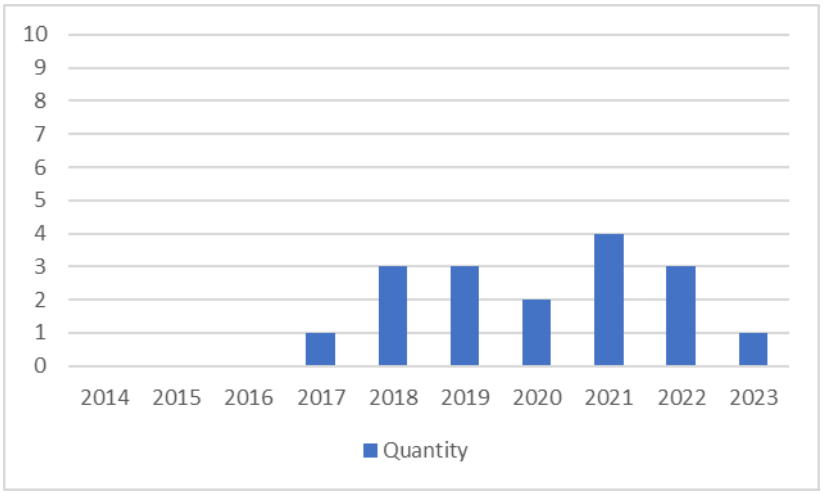

Figure 1. Study Based on Year of Publication

Based on Figure 1, it can be seen that research on refractive thinking in solving mathematical problems began in 2017. The start of this research was triggered by research conducted by Prayitno (2016; 2014) who constructed the components of refractive thinking in solving mathematical problems. No research on refractive thinking in solving mathematical problems was found before 2014 based on a search on Google Scholar and Publish or Perish. Based on this, the results of the research reviewed are research published during the last decade. In addition, several studies were published from 2014 to 2016 but did not meet the inclusion criteria, so the studies were not included in the analysis.

Figure 1 also shows that the most research on refractive thinking in solving mathematical problems was published in 2021 with four articles, while the last was in 2017 with one article. In 2023 there was also only one article but the article in 2023 was taken in the period January to February 2023, so in the following moth there may be research on refractive thinking in solving mathematical problems published.

Study Based on Publication Media

In this study, the inclusion criteria were limited to research published in the repository and indexed journal, namely Scopus, Sinta, and Garuda. The published research is in the form of journal articles, proceedings articles, or final college assignments (final project, theses, and dissertations). There are several studies published in journals indexed in Sinta and Garuda at the same time. To avoid confusion in the analysis, research published in journals indexed in both indexes will be categorized into Sinta indexed

journals. The number of publications on refractive thinking in solving mathematical problems based on publication media is presented in Figure 2.

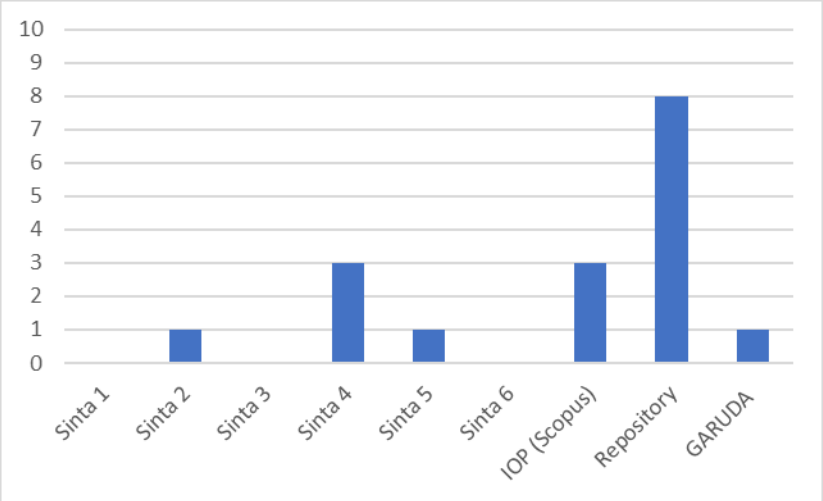

Figure 2. Study Based on Publication Media

In Figure 2, it can be seen that published research in the repository has the highest number of eight research reports. In Sinta 4 and Scopus (IOP), there are three articles. In Sinta 2, Sinta 5, and Garuda, there is one article. There is no research published in Sinta 1, Sinta 3, and Sinta 6. The number of publications in Sinta and Scopus-indexed journals can still be considered relatively low. This can be used as an opportunity for researchers to publish their research in Sinta-indexed journals, especially Sinta 1 (Rum & Juandi, 2022) and Scopus-indexed journals.

Study Based on Demographics

The inclusion criteria in this study were limited to studies on refractive thinking in solving mathematical problems conducted in Indonesia. A description of the studies based on demographics in Indonesia is presented in Figure 3.

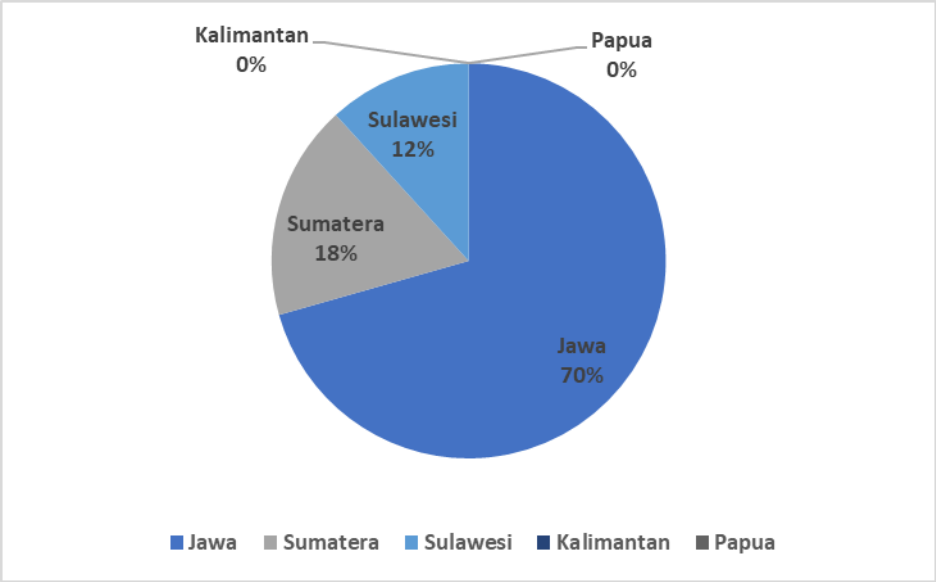

Figure 3. Study Based on Demographics

In Figure 3, it can be seen that research on refractive thinking in solving mathematical problems is mostly conducted on the island of Java at 70%, followed by Sumatera at 18% and Sulawesi at 12%. No related research was found on Kalimantan and Papua. Several Systematic Literature Review (SLR) studies on mathematical ability also found that Java is the most dominating research location (Elmawati & Juandi, 2022; Khairunnisa et al., 2022; Putri & Juandi, 2022; Rum & Juandi, 2022). According to Khairunnisa et al. (2022), Java is the location where the most research has been conducted because half of the population in Indonesia is on the island of Java. This can be used as an opportunity by researchers to conduct research on refractive thinking in solving mathematical problems on other islands besides Java, especially Kalimantan and Papua.

Study Based on The Education Level of Research Participants

The formal education levels in Indonesia consist of elementary school or equivalent, junior high school or equivalent, senior high school or equivalent, and university or higher education. A description of the study based on the education level of the research participants is presented in Figure 4.

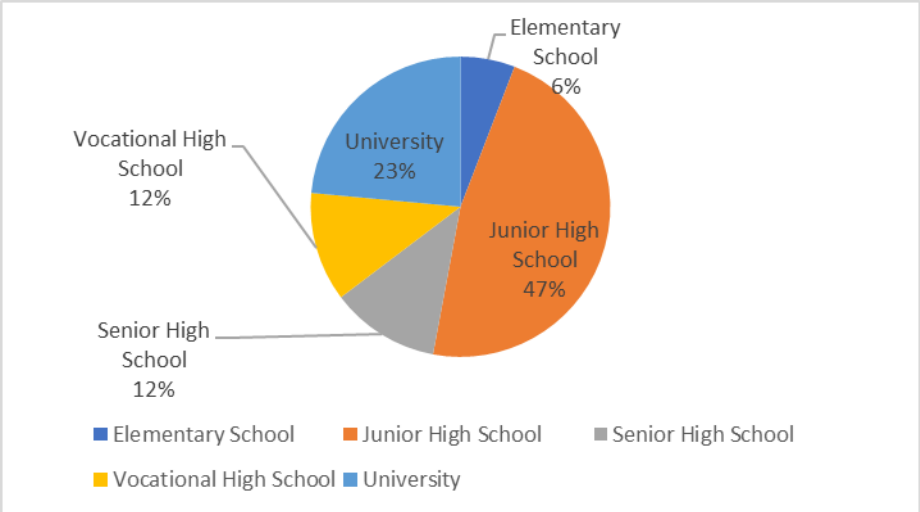

Figure 4. Study Based on The Education Level of Research Participants

Based on Figure 4, it can be seen that research on refractive thinking in solving mathematical problems mostly involves junior high school students or equivalent as participants, which is 47%, followed by high school or equivalent at 24%, university at 23%, and elementary school at 6%. This means that refractive thinking in solving mathematical problems begins to be frequently trained since students are at the junior high school level. Refractive thinking focuses on critical thinking and problem-solving abilities (Pagano & Roselle, 2009), so this also indicates that these two abilities begin to be honed when students are at the junior high school level. This is in line with Juandi's (2021) opinion which states that mathematical abilities, especially mathematical problem-solving ability are learned more at the junior high school level. Elmawati and Juandi (2022) also stated that junior high school students begin to practice all mathematical abilities, especially critical thinking ability.

Figure 4 also shows that there are still very few studies at the elementary level. according to Sukmawati et al. (2017), mathematical ability at the elementary level is a foundation that can help students think at a higher cognitive level. This means that at the elementary level, students learn the basics of thinking mathematically to support their mathematical abilities in the next level of education. This contradicts the instrument used to see the process or measure the ability of refractive thinking. Refractive thinking is one of the higher-order thinking skills. To explore the process of refractive thinking and measure a person's refractive thinking ability, mathematical problems that tend to be complex are needed (Prayitno et al., 2014). In this case, the complex is interpreted as a way of thinking, so the mathematical problems needed to measure refractive thinking are mathematical problems that can make students think complexly. Although it does not rule

out the possibility that elementary school students can already think complexly, in other words at a higher cognitive level, research on refractive thinking in solving mathematical problems at the elementary level may find biased results.

Study Based on The Type of Research

The inclusion criteria in this study were limited to quantitative, qualitative, and mixed-method research types. A description of the studies by research type is presented in Figure 5.

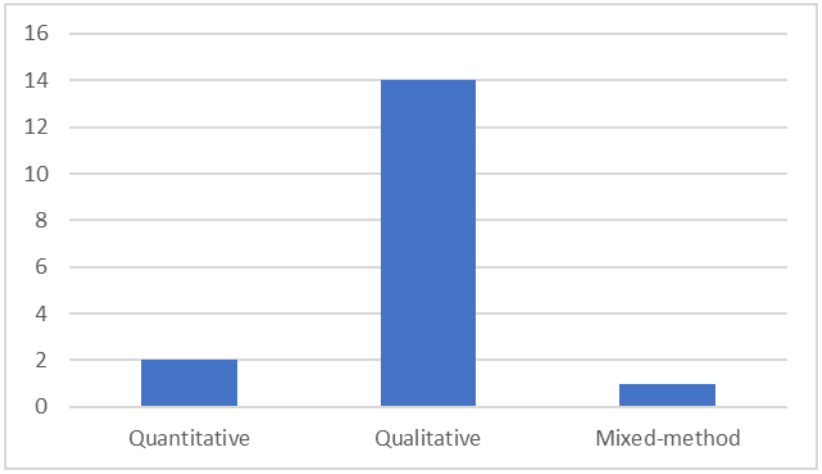

Figure 5. Study Based on Research Type

Based on Figure 5, it can be seen that the highest number of research approaches used in research on refractive thinking in solving mathematical problems is qualitative as many as 14 studies, followed by quantitative as many as two studies, and mixed-method as many as one study. According to Khairunnisa et al. (2022), mixed-method is less desirable because it requires a good understanding of quantitative and qualitative research and the research process is relatively longer than research using one approach.

In addition, the qualitative approach is widely used by researchers because this approach can examine the natural conditions of students (Sugiyono, 2015). This means that students' refractive thinking in solving mathematical problems is studied in actual circumstances without any treatment or action. This is in line with Fadli (2021) who states that in qualitative research, research is conducted in a natural setting, not the results of treatment. In addition, a qualitative approach can find results that cannot be found with a statistical method (quantitative approach) (Sidiq & Choiri, 2019). According to Fadli (2021), a qualitative approach can provide a deep understanding of what is being studied, not just the outside as in quantitative research.

If associated with the number of published research based on the year of publication, the most publications are in 2021. From 2020 to 2021, the world was hit by the Covid-19 pandemic including Indonesia, so the learning process at that time was carried out online. The quantitative approach to educational research uses a lot of experimental methods. In the experimental methods, there is a treatment given to the experimental class (Sugiyono, 2015). This condition makes researchers have obstacles in providing treatment to students. In addition, surveys are also difficult to apply to these conditions, so not many researchers use quantitative approaches.

Study Based on Research Results

The studies on refractive thinking in solving mathematical problems found various results. A summary of the results of 17 published studies sampled in this study is presented in Table 2.

Table 2. Study Based on Research Results

Number	Author (Year)	Research Results Summary
1.	Nurlan, Agustan, dan Sulfasyah (2023)	Refractive thinking ability has a relationship with mathematical literacy skills in 5-grade students.
2.	Sari, Putra, dan Sulisawati (2022a)	9-grade students with introverted personalities did not fulfill the strategy component in refractive thinking.
3.	Sari, Putra, dan Sulisawati (2022b)	9-grade students with extrovert personalities are able to think refractively according to the indicators of refractive thinking in the components of identifying problems, strategy, and evaluations.
4.	Kriswandani dan Kusuma (2022)	The refractive thinking process of students with an intuitive cognitive style in solving problems about scheduling a garment factory passes through the components of the refractive thinking process, namely perplexity, investigation, construct, and evaluation.
5.	Yenti, Kusumah, dan Dahlan (2021)	College students who received Peer-Assisted Reflection learning in multivariable calculus courses experienced an increase in refractive thinking better than students who received conventional learning for all levels of prior mathematical knowledge.
6.	Fatoni, Sujadi, dan	Students' refractive thinking process in solving

Number	Author (Year)	Research Results Summary
	Subanti (2021)	mathematical problems on a system of linear equations of two variables material through the stages of identifying problems, strategy, and evaluations.
7.	Putri (2021)	8-grade students with visual and auditory learning styles did not fulfill the evaluation component, while students with kinesthetic learning styles did not fulfill the strategy and evaluation components.
8.	Yenti (2021)	1) The improvement of students' Mathematical Refractive Thinking (MRT) ability who get Peer-Assisted Reflection (PAR) learning is better than Conventional Learning (CL), both overall and based on Prior Mathematical Knowledge (PMK). 2) Achievement of students with MRT disposition in PAR learning is better than CL for overall and moderate PMK. 3) There is no interaction effect of learning and PMK on the improvement of students' MRT ability and disposition. 4) The complete MRT process occurs in moderate PMK students.
9.	Yenti, Kusumah, Dahlan, dan Fitri (2020)	In solving mathematical problems on multivariable calculus material, college students make mistakes when identifying problems in refractive thinking, which includes errors in reading, interpreting, understanding, and representing ideas in the mathematical language (symbols or figures).
10.	Fatmalasari dan Siswono (2020)	8-grade students with verbalizer and visualizer cognitive styles show indications of refractive thinking in solving problems on geometry material.
11.	Aulia (2019)	In solving change and relationship problems (PISA problems), 9-grade students with monarchic and

Number	Author (Year)	Research Results Summary
		hierarchic thinking styles fulfill all components of refractive thinking, whereas, students with oligarchic and anarchic thinking styles only fulfill the problem identification component in refractive thinking.
12.	Nastiti (2019)	9-grade students with extrovert personalities do not go through the evaluation process in refractive thinking, while students with introverted personalities go through the entire process in refractive thinking.
13.	Ratnani (2019)	10-grade students with climber characteristics fulfill all components of refractive thinking in solving all problems, students with camper characteristics fulfill all components of refractive thinking but the evaluation components did not appear in solving all problems, while students with quitter characteristics fulfill all components of refractive thinking but some problems are not done.
14.	Wafida (2018)	In solving PISA standardized problems, 10-grade students with extrovert personalities do not fulfill the evaluation component in refractive thinking, while students with introverted personalities fulfill all components in refractive thinking.
15.	Oktavia (2018)	In solving problems about data, 10-grade students do refractive thinking in making decisions through the stages of problem identification, strategy, and evaluation.
16.	Maslukha, Lukito, dan Ekawati (2018)	8-grade students with high mathematical ability fulfill all indicators in refractive thinking, and students with moderate and low mathematical ability do not fulfill the indicators in the strategy component in refractive thinking.
17.	Sumarno, Arsyad, dan Asdar (2017)	9-grade students with male gender are able to think reflectively and critically in the refractive thinking

Number	Author (Year)	Research Results Summary
		process, while students with female gender are only able to think reflectively in the refractive thinking process.

In Table 1, it can be seen that research on refractive thinking in solving mathematical problems in Indonesia has been viewed from several aspects, including: 1) introvert and extrovert personalities (Nastiti, 2019; Sari et al., 2022a; Sari et al., 2022b; Wafida, 2018), 2) visualizer and verbalizer cognitive styles (Fatmalasari & Siswono, 2020), 3) monarchic, hierarchic, oligarchic, and anarchic thinking styles (Aulia, 2019), 4) intuitive cognitive style (Kriswandani & Kusuma, 2022), 5) visual, auditory, and kinesthetic learning styles (Putri, 2021), 6) prior mathematical knowledge (Yenti, 2021), 7) adversity quotient (Ratnani, 2019), and 8) gender (Sumarno et al., 2017). Many other aspects can be used to view refractive thinking in solving mathematical problems, such as field-independent and field-dependent cognitive styles, self-efficacy, habits of mind, and others.

Based on the summary of research results presented in Table 1, almost all research results show that research participants fulfill the components in identifying problems. Some studies found that research participants did not fulfill the strategy component (Aulia, 2019; Maslukha et al., 2018; Putri, 2021; Sari et al., 2022a; Wafida, 2018) and evaluation component (Aulia, 2019; Nastiti, 2019; Putri, 2021; Ratnani, 2019; Wafida, 2018). In studies that observe the refractive thinking process, almost all studies show that participants go through the stages of the refractive thinking process well.

Table 1 also shows that learning using Peer-Assisted Reflection (PAR) learning model is better at improving mathematical refractive thinking ability than conventional learning (Yenti et al., 2021). This is because the PAR learning model uses open-ended questions (Reinholz & Dounas-Frazer, 2016). In addition, learning using the PAR model is student-centered and every student must be involved both as a tutor (who teaches) and tutee (who is taught) (Yenti et al., 2021). Only one study was found that examined the improvement of refractive thinking using a particular learning model. This is an opportunity for other researchers to study similar things with other student-centered learning models, such as discovery, inquiry, problem-based learning, and project-based learning.

In addition, some studies study the same thing but there are contradictions in their research findings. Research conducted by Sari et al. (2022a) found that students with introverted personalities did not fulfill the strategy component in refractive thinking, while research conducted by Nastiti (2019) and Wafida (2018) found the opposite, which is students with introverted personalities were able to fulfill all indicators in refractive thinking. This is very likely because the three studies used a qualitative approach. Conclusions in qualitative research cannot be generalized (Hardani et al., 2020), so the results in qualitative research do not apply generally. Although the conclusions do not apply generally, as long as the conclusions are supported by valid and consistent evidence and the research process uses the correct stages, the conclusions produced are credible conclusions (Sugiyono, 2015).

CONCLUSION

Studies on refractive thinking in solving mathematical problems in Indonesia began to become a concern in 2014 until now. The results of the literature review using the Systematic Literature Review (SLR) method show that these studies have been viewed from several aspects, most of these studies show that students are able to meet the indicators of refractive thinking in the problem identification component, some studies show that students have not been able to meet the indicators of refractive thinking in the strategy and evaluation components, and the use of student-centered learning model such as Peer-Assisted Reflection (PAR) can improve mathematical refractive thinking ability. Many of these studies involve junior high school students as participants because mathematical abilities such as problem-solving and critical thinking, which are the focus of refractive thinking, began to be trained at that level. In addition, the type of research most widely used by researchers is qualitative because this approach can provide in-depth knowledge about refractive thinking in solving mathematical problems.

Based on the findings of this study, the recommendation is for future researchers to study refractive thinking in solving mathematical problems using other student-centered learning models such as discovery, problem-based learning, and others to analyze the improvement of students' mathematical refractive thinking ability. In addition, future researchers can study refractive thinking in solving mathematical problems viewed from other aspects such as field-independent and field-dependent cognitive styles, self-efficacy, habits of mind, and others.

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