Higher order thinking skills research trends: a bibliometric analysis in selected journals (2014 to 2023)

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Article Info	ABSTRACT
	This article aims to analyze the trend of higher order thinking skills (HOTS) research in selected journals, namely Journal of Research in Science Teaching (JRST), International Journal of Science Education (IJSE) and Review of Educational Research (RER) through bibliometrics on the Scopus database from 2014 to 2023. The articles consist of a total of 947, then divided into 333 articles analyzed, with details of JRST 113 articles, IJSE 130 articles and RER 90 articles. The method used in this research is article analysis using bibliometric stages, followed by keyword search, initial search results, correction of search results, initial data compilation and data analysis. The results showed that the publication of scientific articles in selected journals on HOTS varied from year to year. The results of this study are expected to help other researchers who are interested in reviewing and researching research trends related to HOTS in selected journals and to recommend further research directions. *This is an open access article under the <u>CC BY-SA</u> license.*

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1. INTRODUCTION

The human resources in the 21st century is claimed to have three essential abilities, namely critical thinking, creative thinking, and problem-solving [1]. These three skills are known as high- level thinking or higher order thinking skills (HOTS). Adapting to the 21st century requires the ability to develop creativity and solve problems [2]. Critical thinking is needed in solving problems, because the rapid development of knowledge and technology has brought the challenges and problems that humanity will face in the 21st century to become more complex [3].

The kind of thinking process that students need to develop to prepare students for the real world must be more than just simple learning about facts and content [4]. High-level thinking skills are an important aspect of teaching learning processes especially in colleges or institutions [5]. Thinking skills training is part of the generic skills that should be embedded in all subject techniques [6]. Students with high-level thinking skills are able to learn to improve their performance and reduce their weaknesses [7].

Current learning should put more emphasis on the aspects of high-level thinking skills [8]. Developing students' HOTS is a complex multidimensional challenge in education [9]. HOTS is the ability to analyze, evaluate, synthesize, and critically evaluate information received [10]. HOTS also points to the ability of students to think at a higher level. Students who have HOTS will be able to analyze, evaluate, and

create innovations in solving environmental problems [11]. HOTS needs in environmental science and learning. That is because of a lot of environmental problems that can be solved using HOTS capabilities [12].

Although biology learning has grown rapidly, there are still some aspects that have not fully facilitated the development of high-level thinking skills. Biology learning is still focused on the absorption of information and the elaboration of concepts, without giving sufficient emphasis to critical analysis, synthesis, and evaluation. Current education places critical thinking and problem solving as competences to be mastered by pupils [13]. HOTS is used to form students who are capable of developing critical, creative, and self-reliant thinking skills [14]. The fact in the field, not all teachers/educators are able to create students who are capable of critical thinking and solving problems in classrooms or in real life situations. One scenario that happens in Malaysia is, teachers are trained to ask HOTS questions only, most of them have very little knowledge of HOTS pedagogics [15]. One of the best ways for students to use critical thinking and problem-solving skills in everyday life is when teachers in schools have good pedagogics, knowledge of HOTS, really understand HOTS then translate that knowledge into everyday lessons so it becomes easier to see changes in student thinking skills [16].

The use of HOTS is not only applicable to a specific level of education, but is expected to apply to all levels of education [17]. The use of HOTS in each level of education varies, depending on the curriculum applied and the purpose of learning [18]. Although HOTS has great benefits in education, the implementation of HOTS in the field is often hampered [19]. These obstacles may include a lack of teachers' understanding of HOTS, lack of support from schools and families, and lack of adequate resources and facilities [20]. Therefore, deeper efforts are needed to implement HOTS in learning. In order to find out the research trends in the field of HOTS then performed analysis like bibliometric analysis [21].

Bibliometrics is a branch of information science commonly used in the field of libraries to know in detail the year of publication, citations, as well as images and graphics that are present in the text of the article [22]. Bibliometrics is widely used to study the interaction between science and technology; investigate new developments in knowledge in a particular field; and produce mapping of fields of science [23]. In looking at HOTS research trends, bibliometric analysis becomes important [24]. Bibliometric analysis can help to see the number and quality of scientific publications about HOTS in selected journals, the authors most involved in this research, as well as the developing research trends in recent years [25].

2. METHOD

Research methods follow bibliometric study guidelines using Google Scholar and Scopus databases because these sources include journals that are considered more relevant by the scientific community, as well as their rigidity and periodicity. The research was carried out using a database from three selected journals namely Journal of Research in Science Teaching (JRST), International Journal of Science Education (IJSE) and Review of Educational Research (RER). The research began with an online search using the Publish or Perish (PoP) application starting October 10, 2023. The steps taken on this study can be seen in Figure 1. Researchers searched articles online by entering keywords "HOTS, science" from 2014 to 2023.

Data search is done using the PoP application. There were 333 documents meeting the search criteria from 947 documents throughout 2014 to 2023. The data obtained from the PoP search results did not all match what the researchers expected, because based on the analysis of researchers through the screening of articles there are still many articles that do not match the research theme, such as the emergence of articles about criticism of politics. Besides, there are also duplicate and inaccessible article data. The data that has been collected is then stored in .ris form. Subsequently, the data obtained is then processed in various programs for bibliometric and network analysis: Microsoft Excel and VOSviewer [26]. The VOSviewer software is used to find trends in research on HOTS [27].
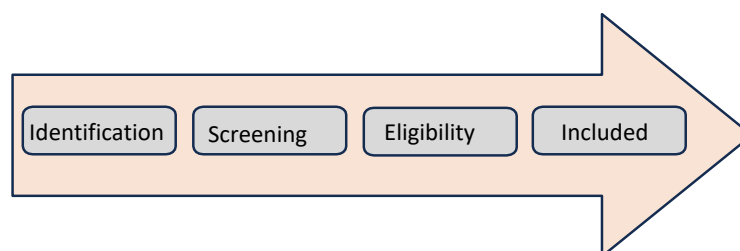
Identification Screening Eligibility Included

Figure 1. Steps in performing bibliometric analysis

The investigation was conducted to analyze research trends that included the profile of publications of HOTS in selected journals, the distribution of the publication of HOTS based on the location of the research, distribution in the subject categories of the study manuscripts of the HOTS, patterns of the dissemination of the HOTs based on fields of science, the dispersion of the high order thinking skills based on educational level, and trends in the study of the HOTS during 2014 to 2023. The emergence of joint keywords is done with VOSviewer, which uses the visualization of similarities (VOS) algorithm as an alternative to multidimensional scaling [28]. Generally speaking, the research procedures carried out in this study was adopted from previous research [29]; it can be seen in Figure 2.

Choosing a 10-year period as the time frame for reviewing the article has some considerations related to decision-making [30]. Here are some reasons why using a 10-year period, namely: using a 10-year period can provide more data and research relevant to the review. This can increase the chances of identifying stronger trends, more established concepts, or gaps in literature. In addition, many scientific research takes place in a particular cycle, like five or ten years. Using a 10-year period, it is possible to see changes and developments over time [31]. Using a rounder period such as 10 years can make it easier to compare reviews of different articles carried out over the same period of time. It can help maintain consistency in scientific research [32].
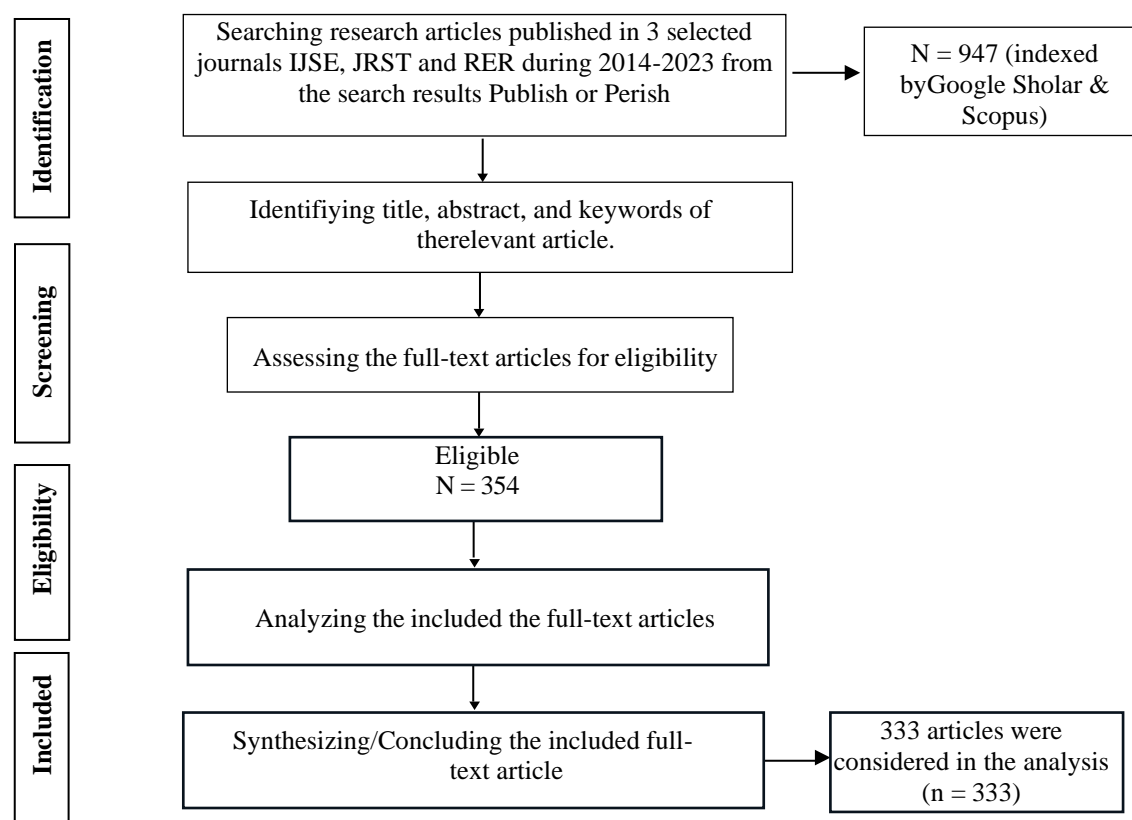

Figure 2. Research procedure

3. RESULTS AND DISCUSSION

Based on bibliometric analysis of the search results PoP can group the articles according to several criteria, i.e., according to the most quotations, the distribution of articles based on the number of scripts per year, country of origin, research methods, HOTS aspects, research type, subject category and visualization of HOTS research trends during 2014 to 2023 using VOSviewer.

3.1. Ranking of higher order thinking skills article writers based on number of citations

The first criterion is the ranking of HOTS article authors based on the highest number of citations; the results can be seen in Table 1. Based on the table, it can be seen that the most citations from the research inquiry with the most number of citation as much as 1999 is on behalf of Abrami, Bernard with the title article "Strategies for teaching students to think critically: a meta-analysis". Besides, the most citations also

obtained articles that study HOTS using different media and learning strategies. It shows that HOTS can be developed with a variety of learning strategies [33], one of which is inquiry, because with learning inquiries students are used to thinking at a high level in learning [34], students are trained to discover their own knowledge through direct observation in the environment around students [35]. Through inquiry can also encourage individuals to find creative solutions to problems or questions they face. This process involves a variety of HOTS skills, such as problem-solving, creativity, and critical thinking [36].

Table 1. Ranking of article writers HOTS by number of citations

Author	Title	Number of citations
Abrami and Bernard	Strategies for teaching students to think critically: a meta-analysis	1999
Kennedy	How does professional development improve teaching?	1680
Evans	Making sense of assessment feedback in higher education	1396
Manz	Representing student argumentation as functionally emergent from scientific activity	1018
Lazonder and Harmsen	Meta-analysis of inquiry-based learning: effects of guidance	966
Lazowski and Hulleman	Motivation interventions in education: a meta-analytic review	812
Thurlings and Tevers	Toward a model of explaining teachers' innovative behavior: a literature review	750
van der Kleij and Feskens	Effects of feedback in a computer-based learning environment on students' learning outcomes: a meta-analysis	735
Kulik and Fletcher	Effectiveness of intelligent tutoring systems: a meta-analyticreview	678
AI Abdul Jabbar and Felicia	Gameplay engagement and learning in game-based learning: a systematic review	657

3.2. Number of manuscripts published higher order thinking skills per year

The publications dedicated to the study of HOTS throughout the year 2014 to 2023 are shown in Figure 3. HOTS research throughout 2014 to 2023. The number of HOTS articles varies from year to year. The full results of the number of HOTS articles during 2014 to 2023 can be seen in Figure 3.
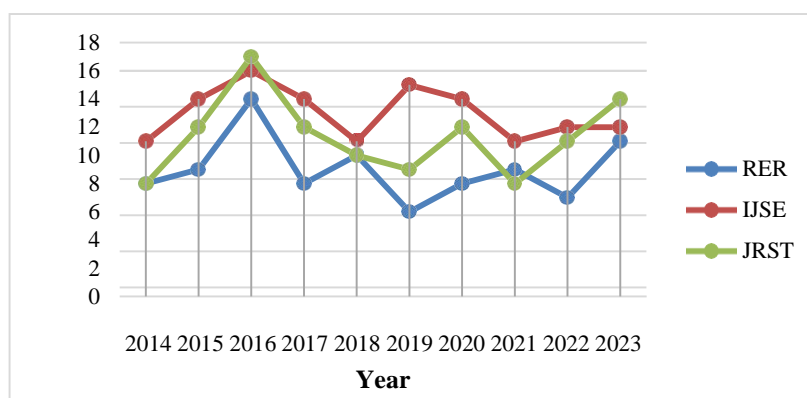

Figure 3. Number of manuscripts published by HOTS each year

Based on Figure 3, it can be seen that if analyzed every year it turns out the number of HOTS research varies and the highest number of Hots research was in 2016 both in the IJSE, JRST and RER. This shows that HOTS study is still an interesting topic to study, either in terms of the implementation of the model, the variables measured, or the methods of research used. According to the analysis of the article there was a decrease in the number of articles in the three journals in 2017 due to the shift in the focus of the priority of the journal that influenced researchers to prefer research topics that are less encouraging or outside the area of HOTS, such as the emergence of research related lower order thinking skills (LOTS). But in the years that followed, the topic of HOTS back became a topic of choice for researchers in the three journals.

LOTS refers to basic level thinking skills that involve understanding, remembering, and applying concrete information [37]. This skill focuses more on the fundamental aspects of a concept or material than on the analysis, evaluation, or synthesis of more complex information. Some examples of LOTS are: memory, understanding, application, classification and comparison [38]. LOTS tend to be concrete and focus on the initial aspects of understanding a matter. Although LOTS is important as a basis for understanding concepts, the objective of higher education is to develop HOTS so that students can carry out analysis, synthesis, evaluation, and application of concepts in more complex contexts [39]. Students usually start by developing LOTS and then progress to a high level of thinking over time and their learning experience.

3.3. Distribution of higher order thinking skills publications by country

Based on the distribution of HOTS publications, it can be seen that the location of research on HOTS varies, and is dominated by the four countries with the highest number of publications in the three selected journals: the United States, the United Kingdom, Australia, and Canada. The full results of the number of HOTS articles by country of origin during 2014 to 2023 can be seen in Figure 4. The five countries with the highest number of HOTS scripts are the United States, the United Kingdom, Australia, Spain, and Thailand. This suggests that HOTS research is still a lot done in different countries, with the research focus in terms of finding and investigating something (objects, humans, or events) systematically, critically, logically, analytically so that they can formulate their own discoveries with confidence.

Based on a review of the HOTS research article, it can be analyzed that in the United States, research on HOTS is more related to curriculum development and evaluation. There is a strong approach to action research, where teachers and researchers work together to design and implement teaching strategies that enhance HOTS, with a focus on evaluating the effectiveness of teaching methods. HOTS research in the UK focuses on integrating high-level thinking skills into educational curricula. There is an interest in measuring and developing analytical, synthesis, and evaluation skills through active learning approaches and collaborative projects. Research in Australia includes efforts to enhance critical and creative thinking skills across educational levels. The research projects focus on the development of instruction that stimulates high-level thinking and the use of technology to improve HOTS.
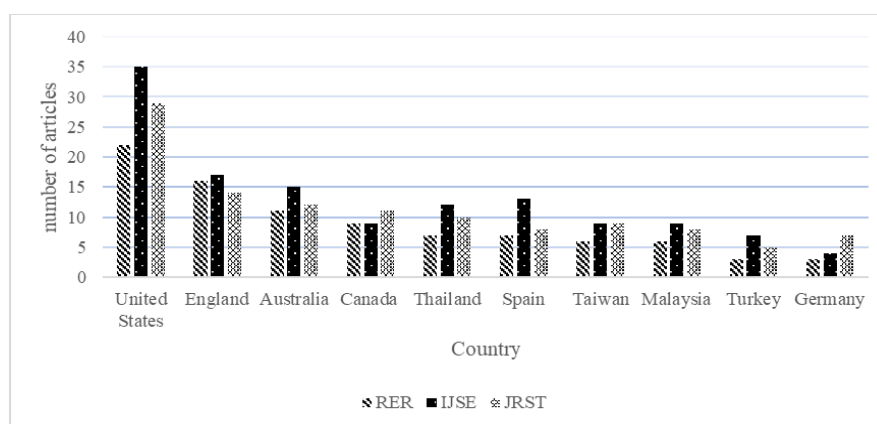

Figure 4. Number of HOTS publications by country

HOTS research in Spain relates to efforts to modernize the education system and adapt it to global demands. Research focuses include the implementation of innovative teaching strategies, the development of a curriculum that supports HOTS, and the evaluation of the learning impact of HOTS. HOTS research in Thailand reflects changes in teaching and learning approaches at the national level. Research focused on the introduction of teaching methods that promote high-level thinking skills in the curriculum.

There are several reasons why research on HOTS is more prominent in the United States, one of which is that the education system in the US, especially at the college level, often emphasizes the development of HOTS [40]. Universities and higher education institutions in America usually place importance on developing high-level thinking skills as part of comprehensive education [41]. The United States has a long history in developing and adopting innovative approaches to education. Many educational institutions in the country are trying to integrate HOTS into their curricula in response to the changing needs of the increasingly complex labor market [42].

3.4. Distribution of higher order thinking skills research script in subject

In terms of research subject categories, Figure 5 shows some research subjects found in HOTS article manuscripts throughout 2014 to 2023, including teachers, lecturers, students, high school students, and high school/SME students. Figure 5 shows the order of the number of scripts published by HOTS according to the category of research subjects are teachers, followed by lecturers. The next subjects are elementary school students, high school students and high school/secondary vocational school students. It shows that HOTS research can be done on different levels of education. It is tailored to the student's level of thinking, because HOTS encompasses high-level thinking skills that are essential for one's intellectual and professional development. HOTS involves critical, evaluative, and analytical thinking skills [43]. These skills are relevant

at all levels of education and help students develop critical thinking towards the information and concepts they face [44]. HOTS incorporates problem-solving skills, which are universal skills required in a variety of life contexts. These skills are relevant from the elementary school level to college and even in the context of work. HOTS covers the aspect of creativity, which is a highly valued skill in various areas of life. High-level education needs to encourage and develop students' creativity to help them become innovative thinkers [45].
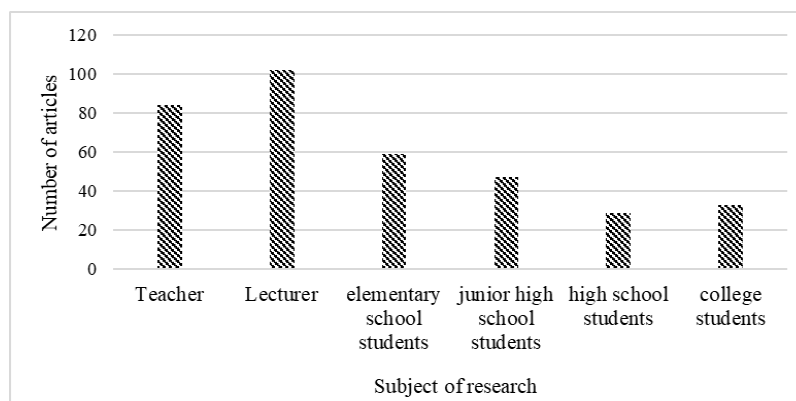
Figure 5. Distribution of HOTS publication script by subject category

3.5. Distribution of research script higher order thinking skills based on research methods

In terms of research methods, Figure 6 shows the methods used in article manuscripts throughout 2014-2023. The figure shows that the most widely used research methods in HOTS publication manuscripts on selected journals are action research, literature review, and survey, so this suggests that the appropriate research method we use to improve HOTS is action research. Action research methods are often considered suitable for enhancing HOTS because they have some advantages and characteristics that match the goal of developing high-level thinking skills [46]. Action research involves the active participation of practitioners, such as teachers, in the research process. Thus, teachers are not only the subject of research but also the main actors involved in learning change and development. Action research focuses on problem solving and improvement within the context of daily activities in the classroom or educational environment [47].

It allows teachers to respond directly to the real needs and challenges their students face in developing HOTS. Moreover, through action research, teachers can feel more empowered in managing and leading change in their classroom. Students can also be involved in the learning process, allowing them to have a more active role in the development of high- level thinking skills. Overall, action research can be a useful and relevant research method to enhance HOTS as it provides space for active involvement, sustained reflection, and contextual adaptation that is essential for the development of high-level thinking skills in an educational context [48].
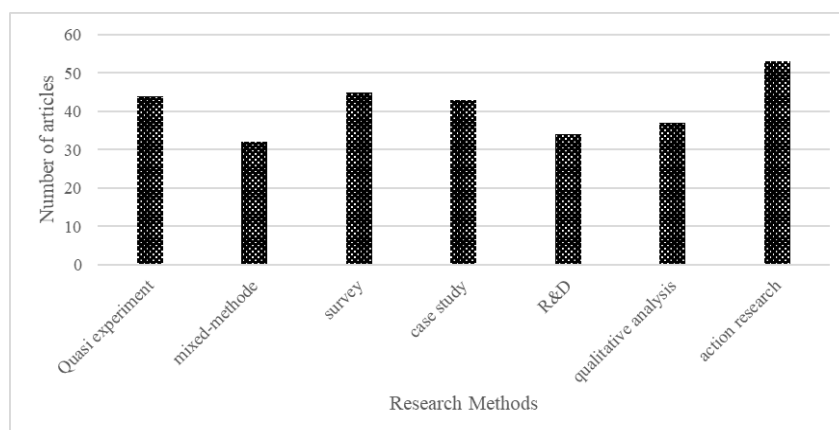

Figure 6. Distribution of the HOTS publication script based on research methods

3.6. Distribution of research script higher order thinking skills based on research

In terms of the type of research script, Figure 7 shows some types of research manuscripts found in the HOTS article script throughout 2014 to 2023, including empirical, position, theory, and review. The figure shows the order of the number of HOTS publications based on the type of research manuscript is the empirical type in both RER, IJSE and JRST journals. Empirical research is much done by researchers because it produces empirical data and concrete evidence that can support claims or findings. In the context of HOTS, it is important to have empirical evidence that can demonstrate the effectiveness of a method or approach in improving HOTS [49]. Therefore, empiric research is often considered more convincing and has a greater impact in shaping learning policies or practices. Empirical research may include studies of student cognitive development and the impact of various learning factors on HOTS [50]. It provides direct insight into the specific ways that approaches or methods can influence the development of HOTS. Empirical research is often easier to adopt by educational practitioners because it provides concrete insights into what works and can be applied in learning settings. It increases the receptivity of research by the educational community and field practitioners [51].
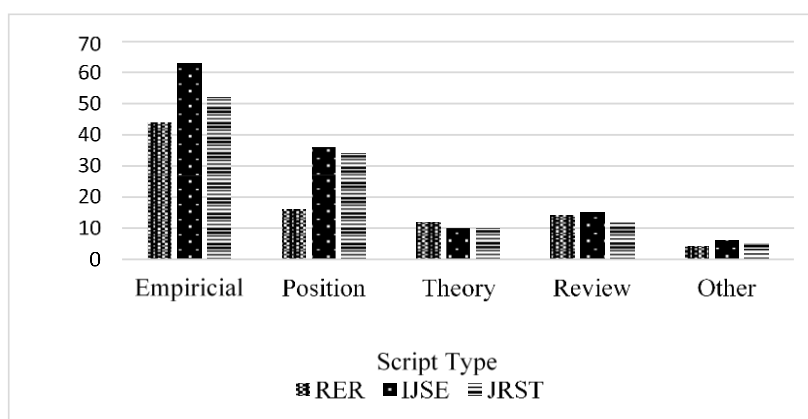

Figure 7. Distribution of HOTS publication script based on research script types

3.7. Distribution of publications based on higher order thinking skills aspects

Based on the distribution of HOTS publications, it can be seen that the aspects studied in HOTS vary in the three selected journals: critical thinking, creative thinking, problem solving and decision making. The results of the distribution of the publication manuscript based on HOTS aspects can be seen in Figure 8. Based on Figure 8, it can be seen that the distribution of research publication manuscripts based on HOTS aspects that are most studied in the three selected journals are critical thinking and problem solving. There are also aspects of creative thinking, decision making, analyzing, evaluating, synthesis, creating, and LOTS. Critical thinking, creative thinking, and decision making are much studied at the student level because at this level, students engage in deeper and more analytical learning [52]. They are invited to question, evaluate, and detail information critically. Discussions and more in-depth research tend to build critical thinking skills. Besides, college programs often emphasize creative problem-solving and innovation. Students often engage in creative projects and research that drive their imagination. Students are also often confronted with situations that require complex decision-making. Decision-making processes based on analysis and evaluation of information are becoming more common. LOTS itself is much researched at the level of primary and secondary education because learning is still focused on increasing knowledge, comprehension, and application [53].

The low level of research on critical thinking, creative thinking, and decision-making occurred in primary schools, due to the focus of development in the new primary school on basic critical-thinking skills such as simple observation, classification, and problem-solving. In terms of creativity, there is indeed great potential for creativity at this level, but it depends on the teaching approach and emphasis on the subject. Furthermore, although the decisions at this level may be simpler, they remain important for children's development [54]. It is important to remember that this level of skill can be influenced by factors such as teacher teaching approach, school curriculum, and support from the environment. Each level of education provides an opportunity to develop these skills in a unique way in accordance with the child's developmental stage.
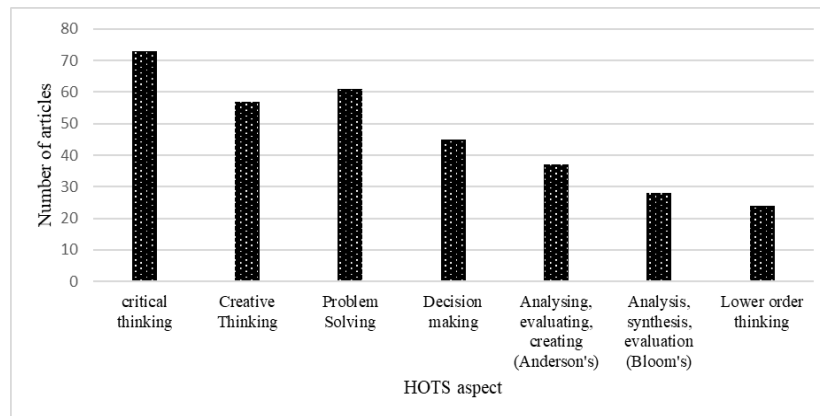
Figure 8. Distribution of HOTS publication script based on HOTS aspects

3.8. VOSviewer software-based inquiry research trends visualization

Research trend mapping is a map visualization that contains topics from science that can help researchers compile their research program. This visualization can be made using VOSviewer. VOSviewer is a computer program developed to create bibliometric maps [55]. Simply put, VOSviewer serves to create, visualize, and explore maps based on various forms of networks that show relationships in the citation of a publication [56]. Bibliometric mapping with VOSviewer typically uses a variety of database sources such as Google Scholar, Crossref, Scopus, Web of Science, and Microsoft Academic Search [33]. While this research uses Scopus and Google Scholar as a database. This is because Scopus and Google Scholar are the largest and most reputable database of national and international scientific publications [57]. Among 333 HOTS research papers produced by searches using PoP with Scopus and Google Scholar databases, researchers were able to visualize the trends of research on the topic of HOTS assisted by the software VOSviewer. VOSviewer's visualization is an attempt to help discover the novelty of research [58]. Figure 9 shows an overview of the study of HOTS. Researchers around the world have produced eight major clusters indicated by the red, green, blue, yellow, purple, tosca, orange, and pink colors. If we examine the specific relationship between variables to capture the trend and novelty of HOTS research, several findings are obtained, indicated by the red, green, blue, yellow, purple, tosca, orange, and pink colors.
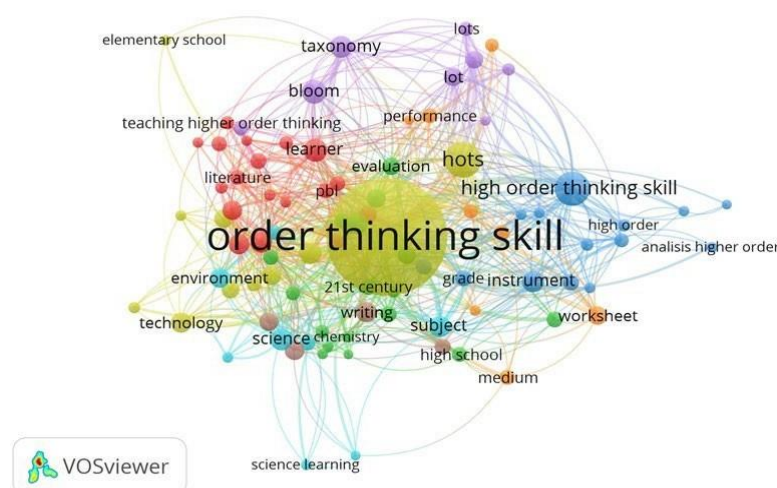

Figure 9. Overview of the HOTS study for 2014 to 2023

Based on the VOSviewer results in Figure 9, it can be explained that cluster 1, namely order thinking skills, indicated by the red line, provides a finding that research on HOTS in the realm of order thinking skills. This is related to the teaching HOTS through the implementation of the problem-based learning model, and the learner of HOTS. Cluster 2, namely evaluation, is indicated by a green line,

emphasizing that research on HOTS in the realm of evaluation is studied. The evaluation tools used in learning HOTS on a number of articles are written subjects, worksheets, projects, and portfolios.

Cluster 3 (HOTS) is indicated by a blue line. This cluster 3 shows that research on HOTS is widely carried out in various areas of learning, such as science learning, chemistry, and environmental education. Cluster 4, technology, indicated by the yellow line, this cluster explains an exploration of how technology can be used to facilitate, strengthen, and develop high-level thinking skills in individuals. These include the use of interactive learning software, simulations, serious games, and online learning environments designed to stimulate critical, analytical, synthetic, and evaluative thinking. Technologies such as online collaborative platforms, design and simulation tools, as well as digital learning resources can be used to enhance students' ability to solve problems and think critically.

Cluster 5, taxonomy, indicated by the purple line, emphasizes that research on of HOTS in the realm of taxonomy. This cluster explores ways to apply taxonomy in teaching and learning to stimulate HOTS. This includes the development of teaching strategies suitable for each taxonomic level, as well as the use of evaluation instruments that can measure students' progress in achieving higher cognitive skills, development of software, applications, and digital platforms designed to help students develop HOTS through structured and measured learning activities, and the preparation of topics, tasks, or projects designed to evaluate high-level cognitive.

Cluster 6, namely subject, is indicated by a tosca color line, through the Inquiry model, students engage in scientific problem solving that involves the active use of critical thinking skills. This model stimulates students to question, analyze, evaluate, and present arguments based on scientific evidence. In this process, students develop critical thinking skills that are important in scientific understanding, decision-making, and problem-solving in everyday life. Cluster 7, worksheet, indicated by the orange line. In this structure, students still have the freedom to conduct their own investigations and discoveries, but with guidance and guidance provided by the teacher.

Cluster 8, creative thinking, indicated by the pink line. This cluster explores how to stimulate, develop, and evaluate creative thinking abilities at a higher level, including the development of teaching methods and strategies designed to encourage creative thinking at a high level. These include the use of project-based learning approaches, problem-based methods, creative problem-solving techniques, and the usage of creative tools such as mind mapping, brainstorming, or attribute analysis. In bibliometric analysis, this cluster can help identify groups of authors or journals that have a research focus on aspects of scientific thinking [59]. It can be used to understand trends in scientific thinking or research methods used in a particular discipline. These clusters can also help in developing teaching or training strategies to enhance scientific thinking skills in a particular field [60]. Through VOSviewer, we can also find out the general description of HOTS learning for 2014 to 2023. Based on the overlay visualization which can be seen in Figure 10.
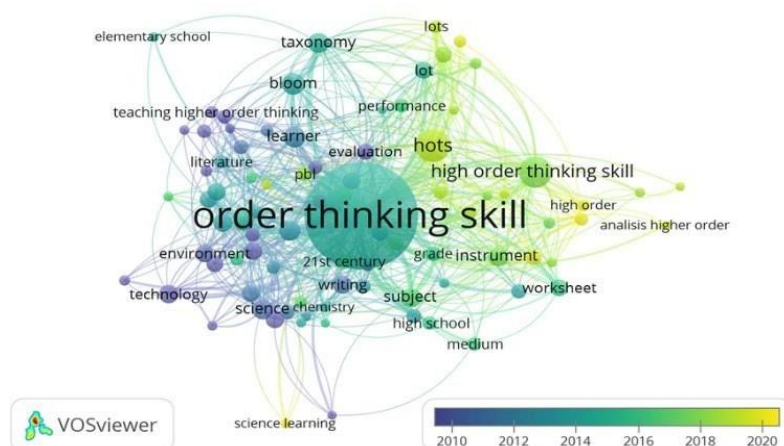

Figure 10. Overview of the HOTS study for 2014 to 2023 based on overlay visualization

In visualizing output of science (VOS) mapping, color bars play an important role in providing useful visual information about the distribution of the data set that is drawn. Color bars provide a visual picture of how often an item (such as a keyword, topic, or document) appears in a drawn data set. Darker colors often indicate higher levels of importance, while brighter colors indicate lower levels of significance.

This helps users to quickly identify the most important or frequently appearing elements in a data set. Using a color bar, users can compare the elements drawn by color intensity. For example, the user can see how the frequency of appearance of a topic or keyword varies between a particular document group or period by comparing the intensity of the color of the bar. By using a color bar, the users can quickly find trends or patterns in the data set that may be difficult to recognize by just using text or numbers.

Based on Figure 10, VOSviewer's overlay visualization shows the topic's freshness, meaning that the brighter the color on the image means the research topics are getting newer, so that research can be done on the latest trends marked with brighter colors on the image VOSviewer's overlay visualization. This shows that the research topics are more curious and much in demand by the researchers. Based on Figure 10, it can be seen the latest topics that can be used as research reference such as the topics higher order thinking skill (HOTS), instruments, and lower order thinking abilities (LOTS). Apart from being based on overlay visualization, we can also understand the general overview of the 2014 to 2023 HOTS study based on density visualization results from VOSviewer, shows that often or not the research is done, which means that the darker the color on the image means that research topics are still rarely done, so if we analyze research on HOTS this can be our consideration to develop research in the present and future.

4. CONCLUSION

In this work, bibliometric methods are used to study the state of research in a particular field of knowledge. HOTS development, identifying the primary source of the number of HOTS researches each year, the spread of the HOTS publications based on the most citations, HOTS components studied during the years 2014 to 2023, the spreading of the Hots publication based on research locations, the distribution of the hots research manuscripts in the subject categories, and the visualization of research trends based on VOSviewer HOTS software during 2014 to 2023 The HOTS trend visualization resulted in 8 main clusters indicated by red, green, blue, yellow, purple, tosca, orange, and pink. The research findings are that HOTS can be developed through action research or case study methods, more suitable to be developed at the educational level in college, with the aspects of HOTS being studied such as critical thinking, problem solving, creative thinking, and decision making through the use of technology-based learning media and use of worksheet. These findings can help relevant researchers to recognize the trends of research in HOTS globally and recommend directions for further research.

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