Research Trends on Scratch in Education and Creative Thinking Skills in Science Education: A Bibliometric Analysis for Last Ten Years (2014-2023)

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Abstract. Scratch in Education plays a crucial role in advancing creative thinking skills, one of the competencies of the 21st century, by providing students with practical experience in designing programming projects, stimulating their creative thinking, and promoting understanding of science concepts through an interactive approach. This research aims to determine the trend of using Scratch programming as a learning medium in science education through bibliometric studies of various article sources from the Scopus database. The methodology used in this study is a bibliometric analysis, which is analyzed using Publish or Perish (PoP) and VOSviewer applications for the last ten years (2014-2023). The results and a total of 584 manuscripts were analyzed. We limit the search in the Scopus database to only the social sciences subject area and document types of article journals and conference papers. The bibliometric analysis reveals several interesting findings. First, there is a growing interest in Scratch programming in science education, as indicated by the increasing number of publications over the last ten years. Second, the identified main research themes include innovative approaches to teaching conceptual sciences to train creative thinking skills using Scratch programming, which still has significant potential for further development. This is depicted in the network, density, and overlay visualizations based on co-citation networks. Third, this study contributes to referencing the relationship between science learning as a field of study and the integration of creative thinking skills and Scratch as a visual coding and programming application. Finally, a discussion and conclusion of the results have been carried out, which can serve as a turning point for future lines of research on scratch programming, science learning, and creative thinking skills.

Keywords: Creative Thinking Skills; Science Learning; Scopus; Scratch-EDU.

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1 Introduction

Children and adults spend hours on various screens in today's digital era, and we increasingly depend on technology. As time passes, hardware, software, and human aspects are increasingly closely intertwined, so the boundaries between the digital world and the natural world are increasingly blurred [1]. Given these trends, many people may need a greater understanding of how to read the language of technology, causing the digital divide to widen and hindering efforts to promote social justice through education [2-3]. It is predicted that students in the future will choose professions that do not yet exist [4-6]. Still, one sure thing is the existence of technology and the need for creative thinking to face situations full of uncertainty, such as flexibility and creative thinking skills in problem-solving [7-8]. As technology becomes more involved in our lives, programming skills will become essential in many professions in the future, on a par with basic skills such as reading and writing [9]. Therefore, there is a tremendous and urgent need to prepare future science teachers to cope with these changes and try to reduce existing gaps.

Regarding the reasons above, as with dynamic science learning, technology integration is becoming increasingly important, revolutionizing traditional teaching and learning paradigms [10-11]. One innovative tool that has gained much attention in the last decade is Scratch, a visual programming language designed to introduce coding concepts to students creatively and engagingly [12]. A comprehensive exploration of research trends surrounding the application of Scratch in education and its impact on developing creative thinking skills, especially in the learning context, must be mapped as a basis for comprehensive and sustainable future research and development [13-14].

Over the past ten years, a growing body of research and literature has investigated various aspects of applying Scratch in science education settings [15-16]. As demand for digital literacy and creative computational thinking skills increases, educators and researchers are seeking to understand the nuances of Scratch's effectiveness as a science education tool [17-18]. This bibliometric analysis aims to provide an overview based on keywords or main themes and new trends that mark the intersection between Scratch, education, and creative thinking skills.

Scratch in Education (Scratch-Edu), related to learning activities from scratch programming, generally refers to learning something entirely new without prior knowledge or experience in that subject [19]. It can apply to various areas, such as learning a new concept of science using interactive simulation, a programming language, or any other skill or knowledge domain. The learning process can begin by reviewing the basic concepts of Scratch and explaining its role in creating an engaging and interactive learning environment [20]. With its user-friendly interface and block-based programming, Scratch demystifies coding for beginners and fosters creativity and exploration [21].

In navigating the diverse landscape of Scratch in science education, bibliometric analysis using VOSviewer will reveal patterns of collaboration and interdisciplinary relationships. The results of this bibliometric analysis aim to provide a roadmap for educators, policymakers, and researchers who want to understand the direction of Scratch in shaping the future of education, specifically science education and its relationship with improving creative thinking skills.

2 Methodology

Bibliometrics is a methodology to explore the evolution and knowledge organization within a specific research domain [22]. This approach comprehensively depicts the broader landscape of a particular research field on a macroscopic scale. Furthermore, bibliometrics facilitates the analysis of specific trending subjects within the field at a more detailed micro level [23-24]. As a result, many scholars have adopted bibliometric techniques in their research endeavors. The data used in this research comes from research published in journals indexed by Scopus. Scopus was chosen as a data source because of its broad coverage in various scientific disciplines, including social, natural, health, and humanities [25]. Regarding quality, Scopus uses a strict assessment method to determine the quality of the journals included in its database [26]. Scopus also provides information about the impact factors of journals listed in its database [27]. The impact factor is one of the leading indicators used to measure how often other researchers cite articles in a journal. This helps researchers understand how much a journal influences a particular field of study. Scopus is widely recognized in the international scientific community [28-30].

A literature review on the selected topic was conducted using Publish or Perish software, a reference management application. A previous study [31] provided detailed information about the use and installation of the software, as well as gradual steps for data acquisition. Additionally, previously explained the methodology for searching data from Scopus through libraries [32].

Using mathematical and statistical methodologies, bibliometrics can examine diverse sets of literature, encompassing books, periodicals, and policy texts [33]. The conventional bibliometrics methodology involves the steps of document collection, data processing, visualization, and analysis, as shown in Fig. 1.

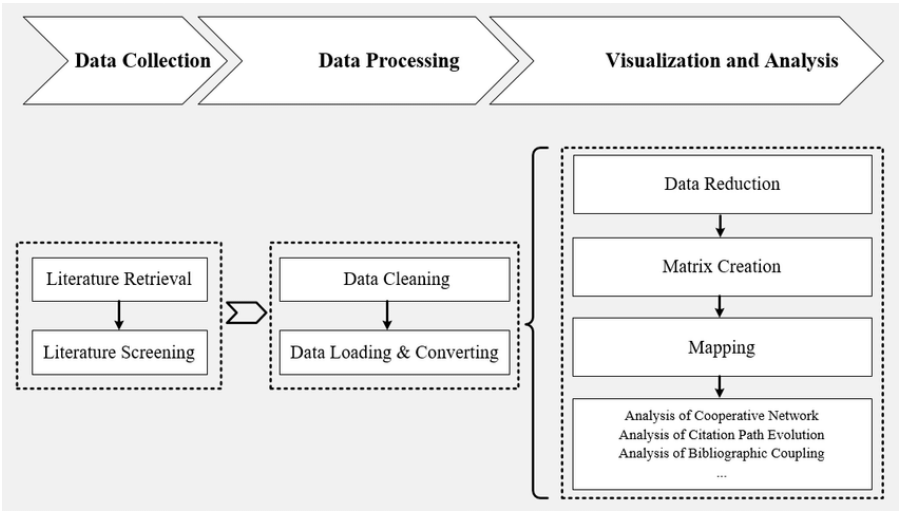

Fig. 1. Research Framework of Bibliometric Analysis According to Xiao et al. (2021)

Data collection in this bibliometric study searches for publication data using the Publish or Perish application, which aims to filter literature retrieval publications by applying the keywords "scratch programming and creative thinking skills in science education." The selected papers were published between 2014 and 2023, and data collection was completed in August 2023. At least 1113 article data were obtained from the results of this search with various document types, subject areas, keywords, and languages. From the data obtained, limitations were then carried out through a literature screening process by setting the subject area provisions only on "social sciences", document types on "journal articles" and "conference papers", the language used was "English", while keywords were carried out the further analysis in the next step.

The next step is data processing, where after data screening has been carried out with various predetermined limitations, data cleaning is carried out for irrelevant data, namely by discarding data that does not meet the specified criteria. Then, the data was loaded and converted, resulting in 590 documents, which were processed in the visualization and analysis steps.

After collecting relevant articles, the results were exported in two file formats: research information systems (.ris) and comma-separated value format (*.csv). VOSviewer is used to visualize and analyze data trends. Article data obtained from the source database was mapped using VOSviewer, which produces three types of publication maps: network visualization, density visualization, and overlay visualization based on co-citation networks between the articles. A minimum keyword frequency threshold is created three times for a bibliometric map.

3 Result and Discussion

In the last ten years, a comprehensive search was conducted in the Scopus academic database to obtain articles related to Scratch programming and creative thinking skills in science education. Based on bibliometric studies with Scopus, data sources are limited to document types in articles and conference papers. The data search was divided into three keyword scopes: Scratch in education, creative thinking skills, and science education. Then, the data was processed using the VOSviewer application, and the analysis focused on co-citation analysis, co-occurrence analysis, and keywords to identify primary research themes and influential publications. The data obtained in this literature study consisted of research published in journals totaling 480 articles and conference papers totaling 110 articles from the Scopus database.

Bibliometric mapping analysis revealed several interesting findings. First, there is increasing interest in Scratch programming and creative thinking skills in science education, as shown by the increasing number of publications in the last ten years. The graph in Fig. 2 shows that the trend of publications on the topic under study is increasing yearly.

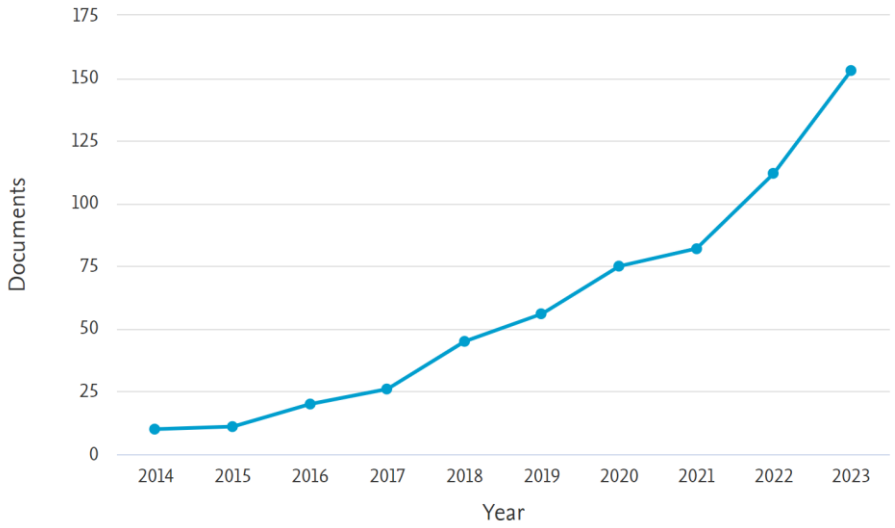

Fig. 2. Publication Trends in Number of Documents by Year

Bibliometric mapping analysis has unveiled intriguing insights into the dynamics of publications related to Scratch programming and creative thinking skills in science education. Notably, the data illustrates a discernible surge in interest, as evidenced by the escalating number of publications over the past decade. Fig. 2 graphically represents this upward trajectory, depicting a consistent annual increase in publications within the specified domain. This notable trend could be attributed to the growing recognition of Scratch as a potent tool for enhancing science education, coupled with the emphasis on fostering creative thinking skills in contemporary educational practices. The visual representation in Fig. 2 underlines the sustained and expanding scholarly engagement with the intersection of Scratch programming, science education, and creative thinking skills.

A further overview of trends is presented in documents by subject area and country/territory, which are presented in Fig. 3 and Fig. 4.

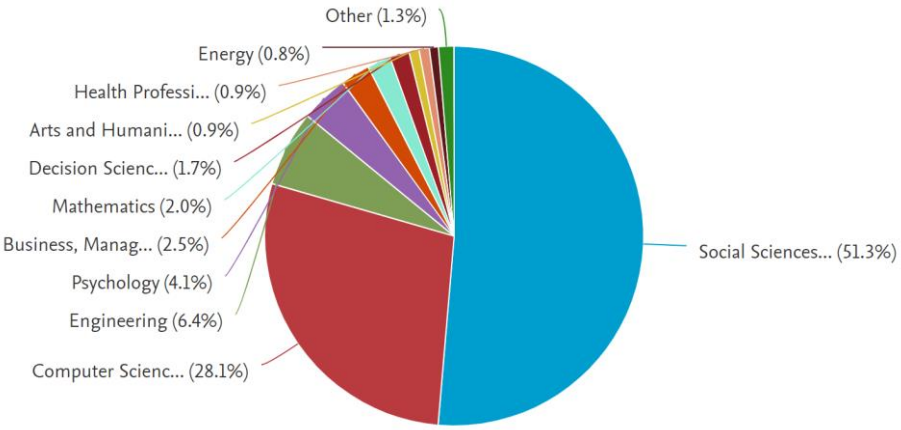

Fig. 3. Publication Trends by Subject Area

Based on Fig. 3, the largest research subject area is Scratch programming and creative thinking skills in science education in social and computer science. Analysis of Fig. 3 highlights exciting facts regarding the subject of the largest research area in the context of Scratch programming and creative thinking skills in science education. From this image, it can be identified that the two main subjects that dominate this research are social science and computer science. Several factors may explain why these two subjects are the main focus of this research. First, the close relationship between Scratch programming and computer science disciplines is a major factor. As a visual programming language designed for creative learning approaches, Scratch has naturally attracted research attention in the context of computer science [14, 34-35]. Developing programming skills and creative thinking through Scratch can be considered a valuable contribution to teaching and learning in computer science [36-37]. Second, the interest in social aspects can be understood from the perspective of implementing Scratch in collaborative and social learning environments. Scratch is often used for joint projects or group activities, where students can work together to develop creative projects [38-39]. Therefore, attention to social aspects may reflect a desire to understand how Scratch can facilitate collaborative learning and social interaction in the classroom.

In addition, Fig. 3 can also reflect a more holistic direction of educational development, where science education is viewed from a purely technical perspective in computer science and a social perspective that considers interactions between individuals and the influence of the environment on learning. Thus, the dominance of social science and computer science subject areas in research on Scratch programming and creative thinking skills in science education can be understood as a response to the complexity and multidimensionality of current education [40-41], which combines technical and social aspects to improve the quality of science learning.

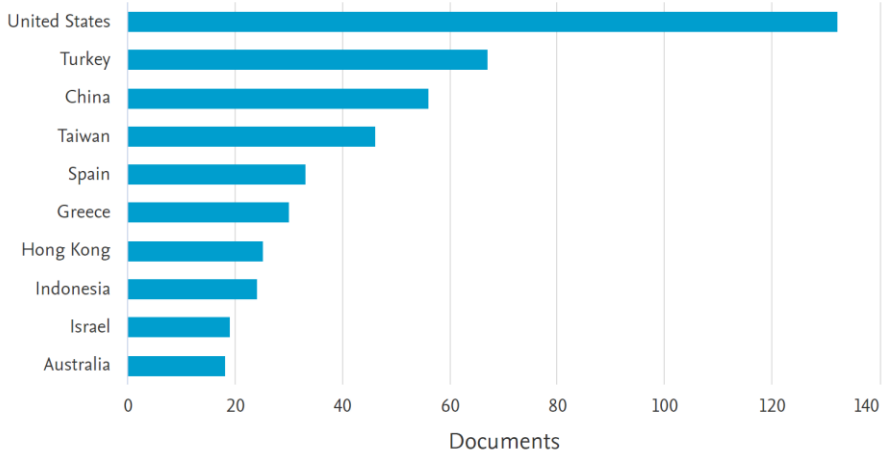

Fig. 4. Publication Trends by Country/ Territory

Fig. 4 shows the top 10 countries that have researched or published the most articles on Scratch programming and creative thinking skills in science education. United States still dominates as the most productive, followed by Türkiye, China, and Taiwan. Indonesia still ranks 8th out of the top 10 countries. Fig. 4 provides a compelling snapshot of the global landscape in research on Scratch programming and creative thinking skills in science education, showcasing the top 10 countries contributing to this body of knowledge. The dominance of the United States as the most prolific contributor underscores its robust commitment to educational research and innovation. Notably, Türkiye, China, and Taiwan are substantial contributors, reflecting a growing international interest and investment in exploring the intersection of Scratch programming and science education. Indonesia's position as the 8th among the top 10 countries highlights its notable presence in this field, indicating a commendable engagement in research endeavors related to Scratch and creative thinking skills in the context of science education. The distribution of research productivity across these countries suggests a global collaborative effort in advancing Scratch's understanding and implementation in educational practices. Fostering a diverse and expansive knowledge base to enhance creative thinking skills in science education worldwide.

The main research themes identified in the following findings are based on VOSviewer software analysis. The results in network, overlay, and density visualization are shown in the following Fig. 5. Fig. 5 presents the relationship between terms visualized through a connected network, which describes the grouping of terms frequently researched and connected to the research topics of Scratch programming and creative thinking skills in science education. This network visualization reveals three distinct research areas on Scratch programming and creative thinking skills in science education. First, "Scratch" is part of cluster 3, characterized by 129 total links, 284 total link strengths, and 63 occurrences. Second, "Creative Thinking" relates to cluster 9, with 37 links, 53 total link strengths, and 14 occurrences. Finally, "Science Education" falls into cluster 9, showing 11 links, 18 link strengths, and seven occurrences.

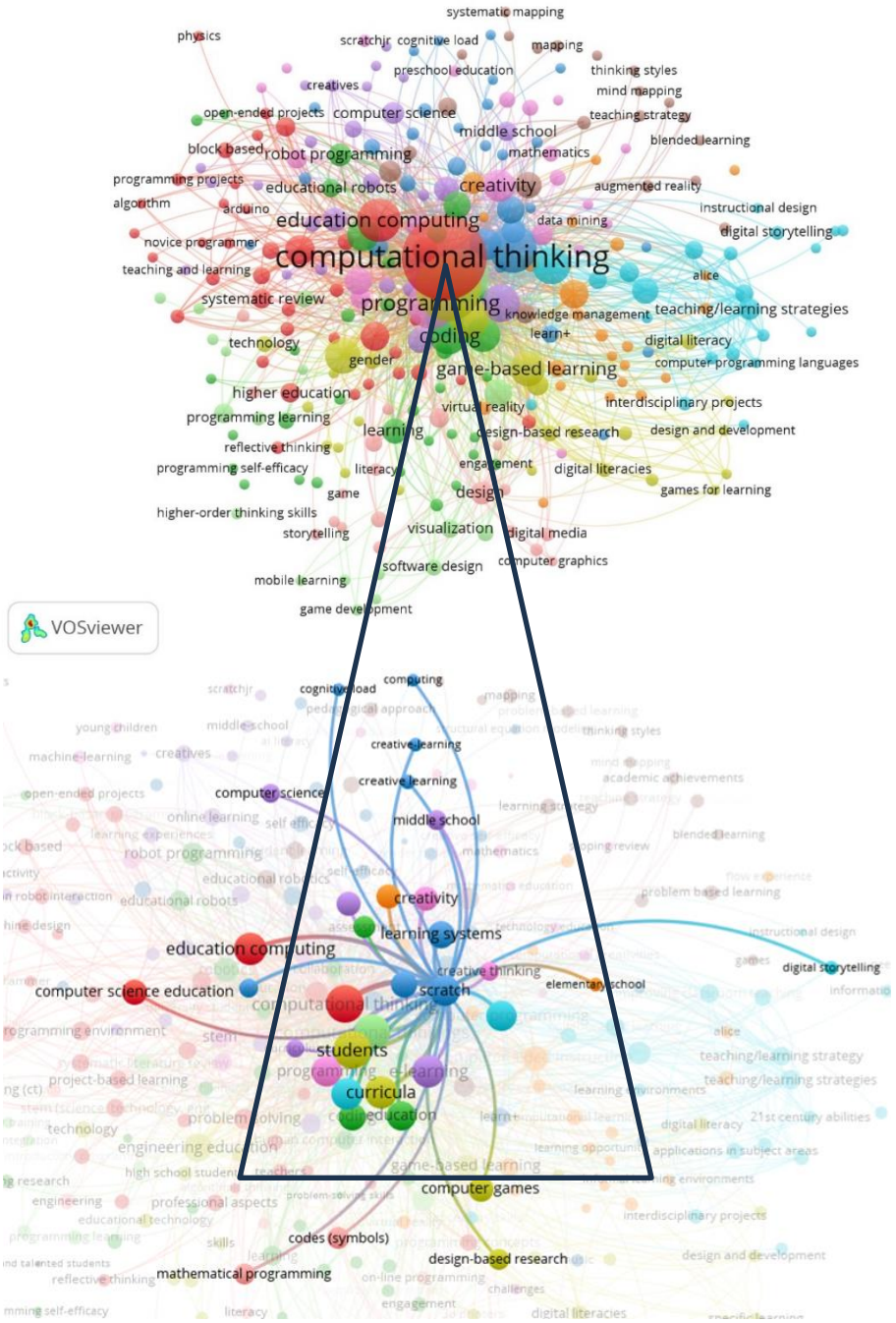

Fig. 5. Network Visualization According to Research Area (2014-2023)

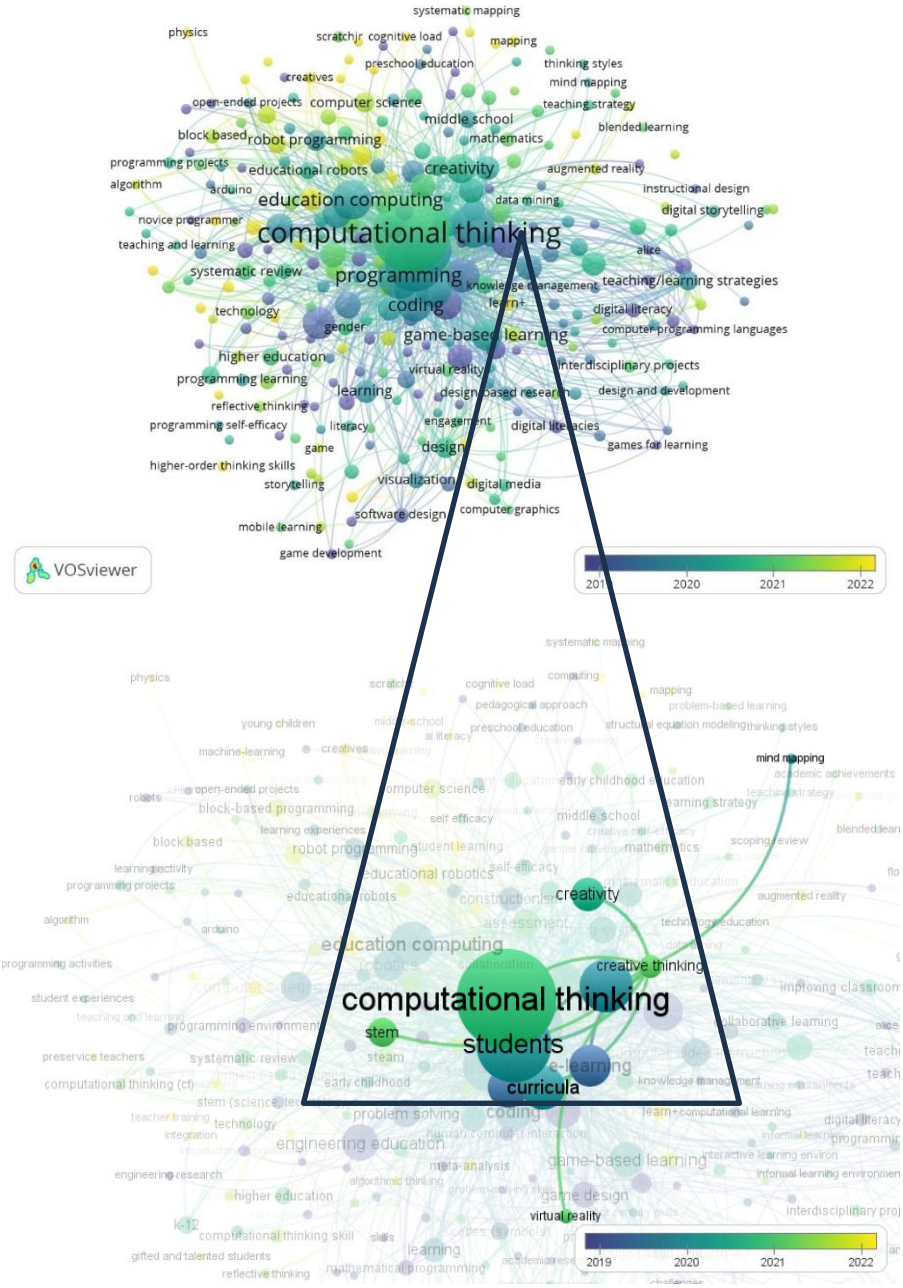

Fig. 6. Overlay Visualization According to Research Area (2014-2023)

The intricate network of research topics within Scratch, Creative Thinking, and Science Education is presented in Fig. 5. This overlapping visualization highlights the interconnectedness of these themes and underscores the burgeoning interest in these areas. Accentuates the contemporary relevance and ongoing exploration within related terms. Over an extended period, the terms Scratch, Creative Thinking, and Science Education have grown in popularity, reflecting a sustained enthusiasm for investigating these subjects.

Fig. 6 displays an overlapping visualization of Scratch, Creative Thinking, and Science Education research topics. This visualization shows the novelty of research regarding related terms [42-43]. Scratch, Creative Thinking, and Science Education have become popular over a long period in research, indicating the ease of conducting new research in this field.

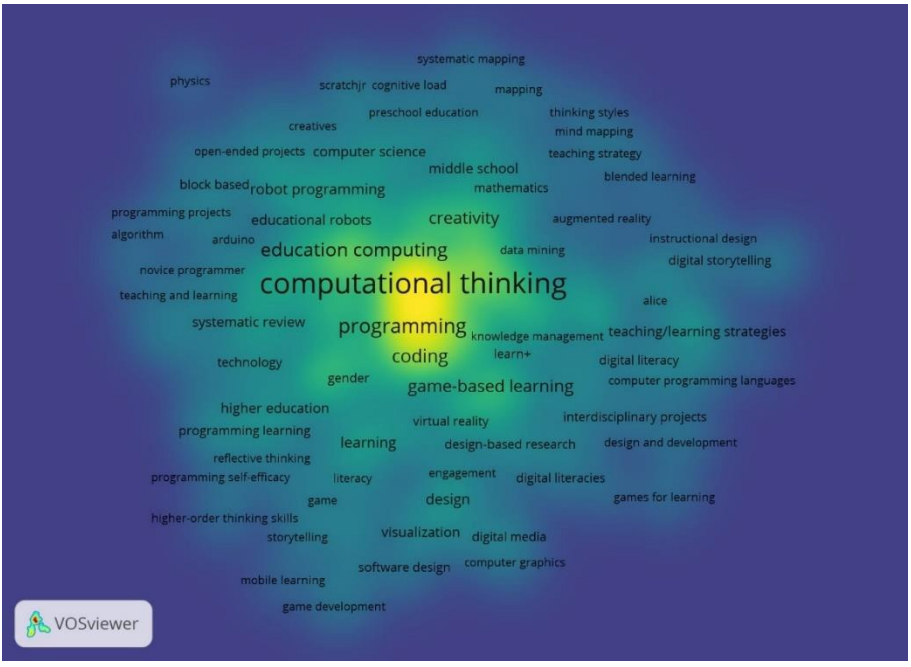

Fig. 7. Density Visualization According to Research Area (2014-2023)

The visualization analysis in Fig. 7 employs color brightness and term label circle size to signify the frequency of occurrence for each term, providing insights into the prevalence of research topics. The lighter and larger circles, represented in yellow, indicate a higher frequency of research on the corresponding term while fading colors closer to the background suggest less research emphasis. Notably, terms such as "computational thinking”," education computing”, and "programming" stand out with their vibrant colors and prominent sizes, indicating that they have garnered substantial attention in academic research. These terms appear pivotal and have been the focal

points of extensive research endeavors, underscoring their significance in the scholarly discourse on Scratch, Creative Thinking, and Science Education.

Based on the results of our analysis from various article sources that have been obtained that have gone through predetermined filtering and restrictions, it can be described as follows. The findings derived from the VOSviewer software analysis, as depicted in Fig.s 5, 6, and 7, offer a comprehensive understanding of the leading research themes and their evolving dynamics within Scratch programming and creative thinking skills in science education. Fig. 5's network visualization illustrates three distinct clusters, with "Scratch" forming a central part of cluster 3, indicative of its prominence with 129 total links, 284 link strengths, and 63 occurrences. The interconnection with "Creative Thinking" and "Science Education" in cluster 9 further underscores the intricate relationships among these themes. Fig. 6's overlay visualization highlights the novelty of research in these domains, emphasizing the sustained popularity of Scratch, Creative Thinking, and Science Education as research topics over an extended period. Fig. 7's density visualization employs color brightness and term label circle size to convey the frequency of occurrence, illuminating the central role of terms like "computational thinking," "education computing," and "programming," which have garnered significant attention in academic research. The visualization collectively accentuates the dynamic and interconnected nature of research within these themes, underscoring the enduring scholarly enthusiasm and contemporary relevance in exploring Scratch, Creative Thinking, and Science Education.

The discussion of the research results reveals a comprehensive analysis conducted over the past decade, utilizing the Scopus academic database to gather articles on Scratch programming and creative thinking skills in science education. Employing bibliometric studies and VOSviewer application for analysis, the study focuses on co-citation and co-occurrence analysis, providing insights into primary research themes and influential publications. The findings depict a substantial and increasing interest in the intersection of Scratch programming and creative thinking skills, as evidenced by the growing number of publications. Fig. 2 visually represents this upward trend, emphasizing the sustained scholarly engagement in exploring the potential of Scratch within science education. Further investigation into subject areas reveals a predominant focus on social and computer science, reflecting the close relationship between Scratch and computer science disciplines and the interest in collaborative learning environments. The global landscape of research, presented in Fig. 4, identifies the United States as the leading contributor, followed by Türkiye, China, and Taiwan, showcasing a diverse and collaborative effort in advancing knowledge on Scratch programming and creative thinking skills in science education.

The VOSviewer analysis in Fig.s 5, 6, and 7 uncovers distinct research clusters, emphasizing the interconnectedness of Scratch, creative thinking, and science education themes. Terms such as "computational thinking," "education computing," and "programming" emerge as pivotal, indicating their central role in academic research and highlighting the dynamic and enduring scholarly enthusiasm for exploring these themes. The study provides a comprehensive overview of the evolving dynamics and

global trends in Scratch programming and creative thinking skills in science education, offering valuable insights for educators, policymakers, and researchers.

4 Conclusion

The findings derived from the bibliometric analysis offer valuable insights into several noteworthy trends. Firstly, there is a noticeable surge in the interest surrounding Scratch programming within science education, as evidenced by the escalating volume of publications over the past decade. Secondly, the primary research themes identified revolve around inventive methodologies aimed at imparting conceptual sciences while cultivating creative thinking skills through Scratch programming. Notably, these themes exhibit substantial potential for further expansion and refinement, as illustrated by the visualizations portraying network, density, and overlay based on co-citation networks. Thirdly, this study makes a significant contribution by elucidating the intricate relationship between science learning as a field of study and the amalgamation of creative thinking skills with Scratch, a visual coding and programming tool. Finally, a comprehensive conclusion of the results has been presented, serving as a pivotal juncture for shaping the trajectory of future research endeavors in Scratch programming, science education, and the enhancement of creative thinking skills.

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