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Mapping the Integration of CLIL and STEAM in Secondary Education: A Bibliometric Study

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ABSTRACT

The convergence of science and language education is becoming increasingly vital in modern secondary schooling. Content and Language Integrated Learning (CLIL) and STEAM are emerging as powerful frameworks for this interdisciplinary instruction, yet their combined implementation patterns and conceptual linkages remain under-explored in current literature. This study aims to identify dominant topic trends within scientific literature regarding the implementation of CLIL and STEAM. It specifically analyzes integration patterns between these approaches in secondary education to reveal research gaps and future opportunities for integrated science and language-based learning. A bibliometric analysis was conducted to map the research landscape. This involved visualizing keyword co-occurrences to identify thematic clusters and relationships between supporting themes such as curriculum design, learning technology, and bilingual education. The analysis reveals a strong correlation between STEAM, CLIL, and the secondary education context, particularly in Spain, the USA, the UK, and Indonesia. Distinct clusters emerged around 21st-century skills and creativity, while a specific CLIL cluster highlighted bilingualism and motivation. Crucially, the linkage between STEAM and CLIL is driven by concepts like project-based learning, demonstrating a growing pedagogical synthesis supported by technological innovation. Findings confirm a distinct shift toward integrated STEAM–CLIL approaches. This trajectory highlights a significant opportunity for researchers and practitioners to develop innovative, coherent learning models that simultaneously enhance scientific literacy and foreign language proficiency in an interdisciplinary manner.

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INTRODUCTION

The era of globalization and the industrial revolution has impacted global education, requiring students to master academic knowledge and master 21st-century skills, including critical thinking, collaboration, communication, and creativity (Dilekci and Karatay, 2023). Therefore, learning needs to be implemented contextually, meaningfully, and sustainably to connect scientific knowledge with students' social and cultural realities. Integrating culture as a knowledge context and technology-based learning can support active learners, meaningful learning, and lead to educational sustainability (Nasution et al., 2025). Furthermore, technology-based learning media with an artistic context can help students understand complex knowledge such as science (Nasution et al., 2024). However, contextual learning needs to be delivered using appropriate language to explain the content discussed to avoid multiple interpretations and misconceptions.

One solution to addressing misconceptions is the implementation of Content and Language Integrated Learning (CLIL) to assist with complex conceptual representation. The use of conceptual representation tools such as concept mapping has also been shown to assist educators and students in exploring and

constructing more structured and meaningful conceptual understanding (Suprapto et al., 2018). This supports CLIL's alignment with STEAM, which emphasizes contextual, interdisciplinary, and conceptually oriented learning in learning content. Within the CLIL framework, learning focuses not only on language mastery as the goal but also on understanding academic content through the use of language as a medium for thinking and communicating (Rachel and Anne, 2023).

The STEAM approach, on the other hand, integrates science, technology, engineering, arts, and mathematics into authentic project-based learning activities to enhance students' analytical, creative, and collaborative skills. Studies show that STEAM pedagogy can expand CLIL practice by providing a rich pedagogical framework through models such as the 6Es (engage, explore, explain, engineer, enrich, and evaluate), which help learners build disciplinary literacy and language skills simultaneously through multidimensional learning experiences (Imamyartha et al., 2024). Furthermore, STEAM's interdisciplinary approach, which incorporates aspects of the arts and humanities, enriches the learning experience and encourages creativity and problem-solving in line with the content being discussed (Perignat and Katz-Buonincontro, 2019). Therefore, it aligns with CLIL learning objectives, which emphasize the use of language as a tool for constructing meaning within the context of content.

The relationship between the Content and Language Integrated Learning (CLIL) and STEAM approaches can be examined more systematically through bibliometric analysis, given that both approaches are rapidly developing but originate from different research traditions, namely language education and interdisciplinary science education. Bibliometric analysis allows for quantitative and visual mapping of publication trends, researcher collaborations, dominant keywords, and conceptual relationships between research topics. Through techniques such as co-occurrence, co-citation, and bibliographic coupling, bibliometric analysis can reveal the extent to which CLIL and STEAM have been integrated in scientific literature, as well as identify areas of intersection, research strengths, and underexplored research gaps. This approach is widely used in educational studies to understand the intellectual structure of a field and the direction of research development globally (Aria & Cuccurullo, 2017; Donthu et al., 2021; Suprapto, 2023). Therefore, bibliometric mapping of the relationship between CLIL and STEAM is relevant and strategic in providing a comprehensive overview of research track records and potential future study developments, as detailed below.

1. Identifying dominant topic trends and conceptual linkage patterns in scientific literature discussing the implementation of CLIL and STEAM, including the role of supporting topics such as curriculum, learning technology, and bilingual education.
2. Analyzing patterns of integration between CLIL and STEAM approaches in secondary education research to uncover research trends and opportunities for developing integrated science- and language-based learning in the future.

RESEARCH METHOD

The bibliometric research method in this study was implemented through systematic stages, including five stages to achieve the research objectives, as shown in Figure 1.

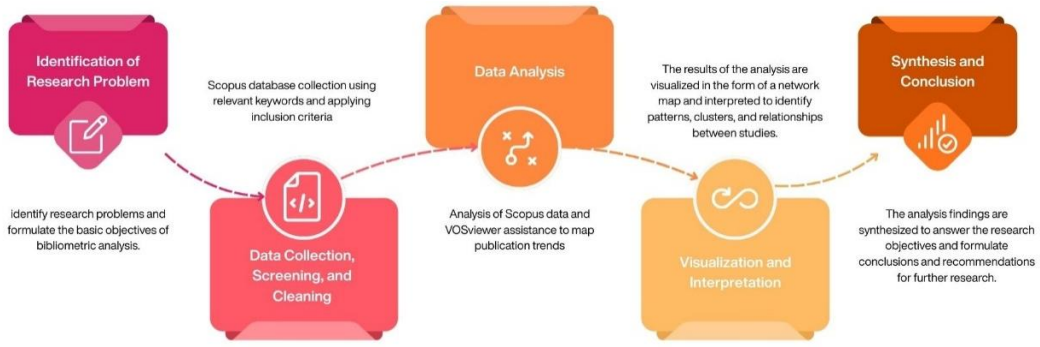


Figure 1. Visualization of keyword network

Figure 1 shows the stages of bibliometric research, starting with the identification of the research problem, namely problem identification as the process of determining the focus of the study and formulating research objectives related to CLIL and STEAM literature mapping. The next stage is data collection, which is carried out by searching the Scopus database using relevant keywords and applying inclusion and exclusion criteria. This process is followed by data filtering and cleaning to ensure the quality and relevance

of the documents analyzed. The entire article selection process is carried out systematically, referring to the PRISMA stages as shown in Figure 2. The validated data is then analyzed using VOSviewer software to identify publication trends, keyword relationships, and thematic clusters. The results of the analysis are then presented through visualization and interpretation in the form of a network map to reveal patterns, relationships, and conceptual structures in the literature. The final stage of the research is synthesis and drawing conclusions, which is carried out by integrating bibliometric findings to answer the research objectives and formulating implications and recommendations for further research.

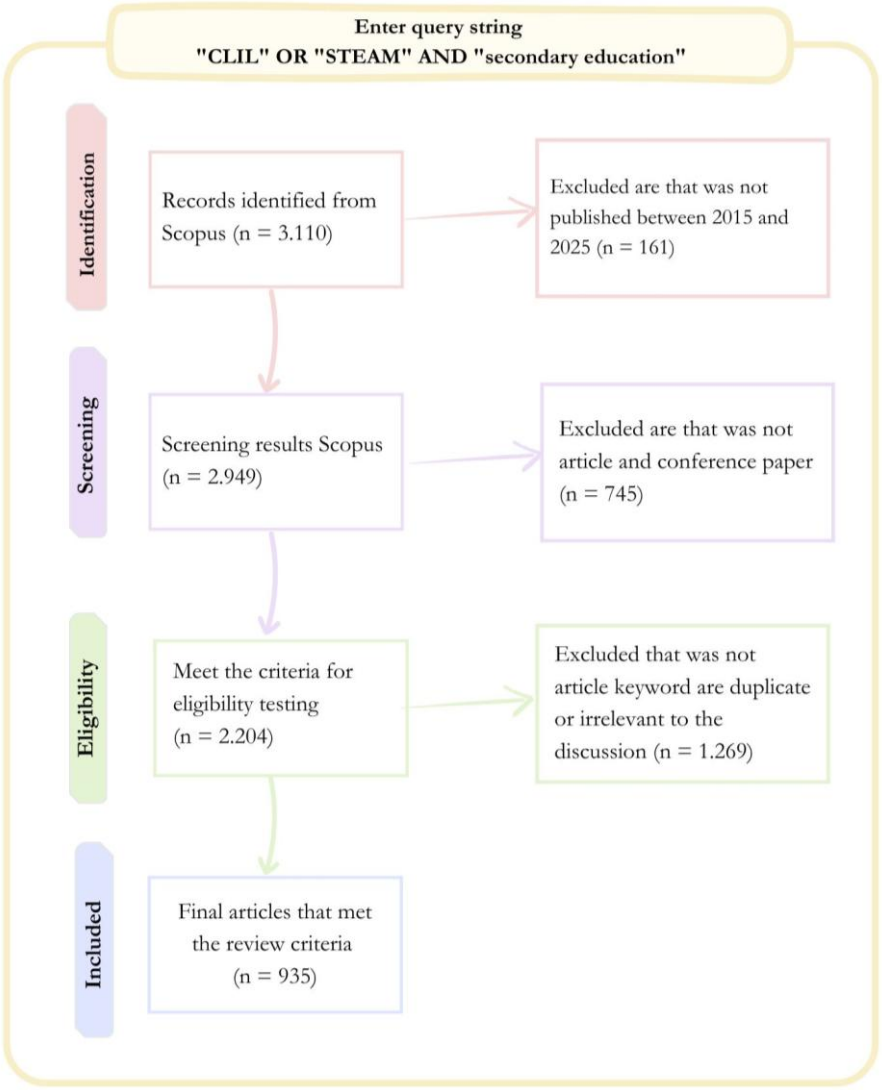


Figure 2. Visualization of keyword network

Figure 2 shows the data collection period from 2015 to 2025. The timeframe for data collection was determined because it was important to ensure the study remained current and relevant (Shaffril et al., 2020). The collected data was filtered using the PRISMA 2020 guidelines. Page et al. (2021) emphasized that using the PRISMA 2020 guidelines in a literature search can improve transparency, reliability, and methodological rigor in systematic review results. The literature search, using keyword identification, facilitated answering the research question, followed by a screening phase aimed at eliminating irrelevant articles. Therefore, it was necessary to establish inclusion and exclusion criteria in the process of selecting appropriate literature for analysis and synthesis. These criteria were created to ensure the quality and relevance of the selected studies and to maintain objectivity in decision-making based on available evidence (Smela et al., 2023).

RESULTS AND DISCUSSION

Result

Research on Content and Language Integrated Learning (CLIL) and STEAM in the context of secondary education was mapped through a bibliometric analysis, initially mapping the distribution of global research contributions, specifically across the 25 countries with the highest number of publications in this field. The mapping results are shown in Figures 1 and 2.

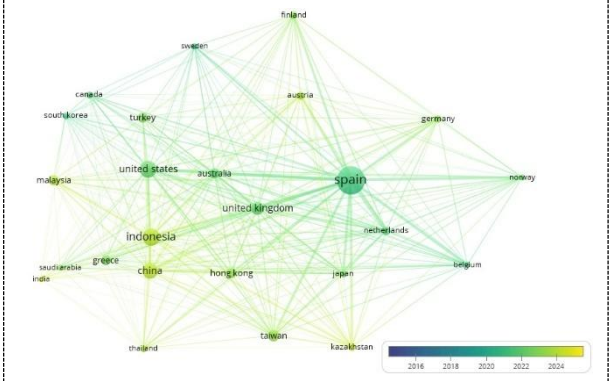


Figure 3. Overlay visualization top 25 country.

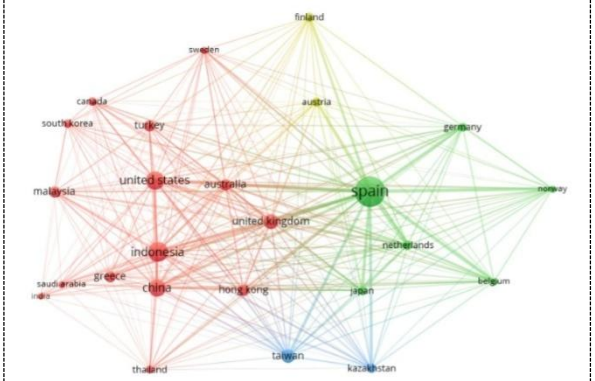


Figure 4. Network visualization top 25 country.

Figures 3 and 4 present a visualization of the international collaboration network by country in research addressing CLIL and STEAM in the context of secondary education. Each node represents a country, while the connecting lines indicate the intensity of research collaboration between countries. The size of the node reflects the country's relative contribution to the number of publications, while the density and thickness of the lines indicate the strength of collaborative relationships. This visualization shows that countries such as Spain, the United States, the United Kingdom, and Indonesia serve as key nodes with strong links to other countries, indicating their central role in the development and dissemination of CLIL and STEAM research globally. Figure 3 also shows the most frequently occurring research years. The color gradient at each node indicates the average publication year, with darker colors indicating relatively earlier research, while lighter colors represent more recent publications. This visualization shows that most of the top 25 countries in CLIL and STEAM research began actively publishing in the early 2020s. Indonesia appears to have made a significant research contribution and is still active to date, as indicated by the yellow color of the nodes, indicating relatively recent publications. However, the country with the highest number of publications in this field is Spain, which shows consistent research activity from the early 2020s until now, as reflected by the predominantly bright green node color.

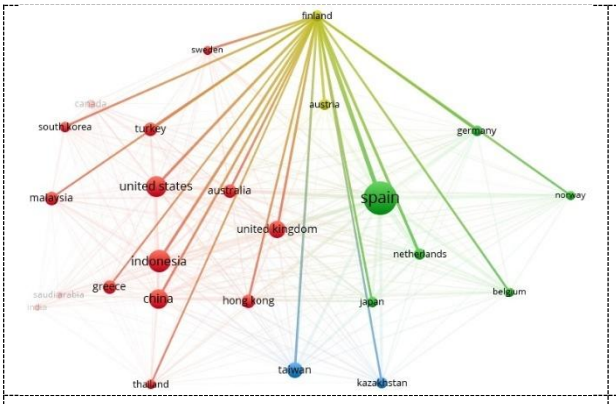


Figure 5. Network visualization focusses on Finland.

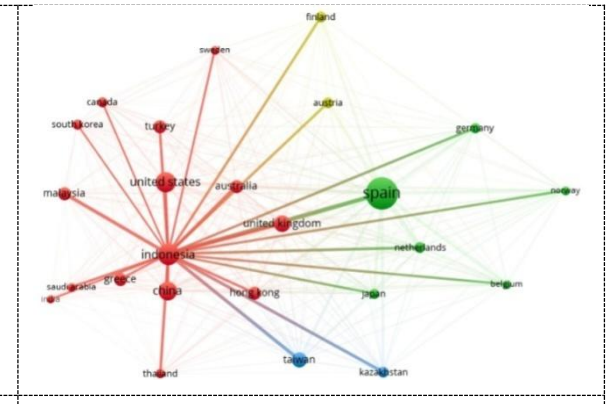


Figure 6. Network visualization focusses on Indoenesia

Figure 5 shows a network visualization focusing on Finland. Finland, widely recognized as having one of the best education systems in the world, also demonstrates active involvement in CLIL and STEAM-related research and has collaborative relationships with several countries that are among the 25 countries with the highest publication contributions in this field. Finland's presence in the international collaboration

network confirms its role as a conceptual and pedagogical reference in the development of innovative learning, particularly those that emphasize the integration of language, science, and interdisciplinary approaches. However, the network visualization results indicate that to date there has been no direct collaboration between Finland and several countries, such as Canada, Saudi Arabia, and India, in the context of CLIL–STEAM research. This finding indicates a strategic opportunity to expand cross-border collaboration in the future, especially with countries with diverse educational characteristics and challenges, to enrich global perspectives and strengthen the development of adaptive and contextual CLIL–STEAM learning models. On the other hand, Figure 6 shows a network visualization focusing on Indonesia, one of the ASEAN countries that has collaborated with all of the top 25 countries in this study.

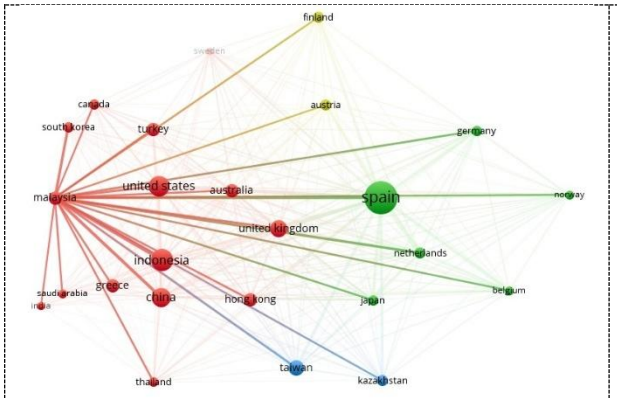


Figure 7. Network visualization focusses on Malaysia.

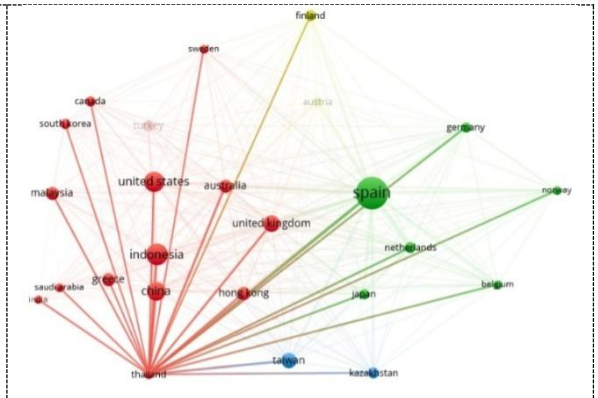


Figure 8. Network visualization focusses on Thailand.

ASEAN countries included in the top 25 countries besides Indonesia are Malaysia and Thailand. However, the results of the international collaboration network visualization show that the collaboration patterns of these two countries with other countries in the top 25 group are still relatively limited compared to Indonesia, which has established collaborative relationships with all countries in the group. In terms of scientific productivity, the number of Indonesian publications on CLIL and STEAM topics is also seen from the visualization exceeding Malaysia and Thailand. This finding indicates that Indonesia not only has a more intensive level of research engagement but also plays a more active role in international collaboration networks. This proves that CLIL-STEAM research in Indonesia is developing progressively, is open to global collaboration, and has strong potential to become one of the centers for the development of integrated science and language learning studies in the Southeast Asian region.

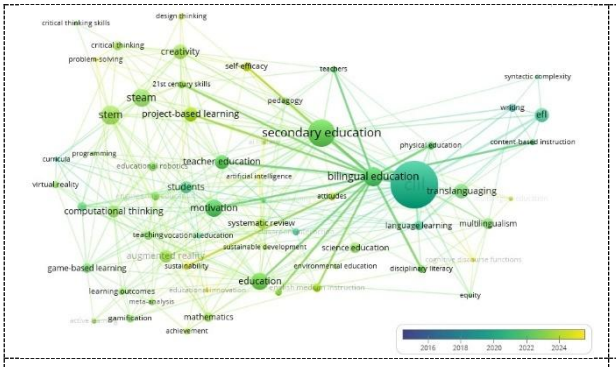


Figure 9. Overlay visualization co-occurrence.

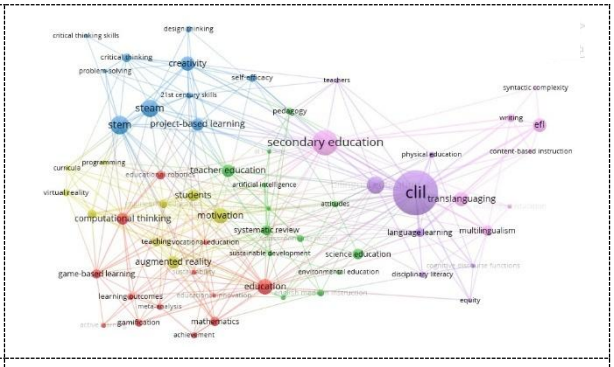


Figure 10. Network visualization co-occurrence.

On the other hand, research on CLIL and STEAM in the context of secondary education is mapped through bibliometric analysis focusing on the relationships between keywords as shown in Figures 9 and 10. This mapping aims to reveal the structure of research themes and conceptual links between fields of study. The visualization results show that secondary education is the central node connecting two main clusters, namely the CLIL cluster and the STEAM cluster. In the CLIL cluster, keywords such as translanguaging, multilingualism, language learning, and content-based instruction appear to be strongly connected, reflecting the research focus on the integration of language and academic content. Meanwhile,

the STEAM cluster is dominated by keywords such as project-based learning, creativity, critical thinking, design thinking, and motivation, which indicates an emphasis on developing 21st-century skills. The research trend, as seen from the VoSviewer overlay output, shows that this topic has been widely discussed since the 2020s until now, and the central keyword is CLIL. The interconnectedness of these clusters indicates a trend in research that integrates the CLIL approach with STEAM learning as an innovative pedagogical strategy in secondary education.

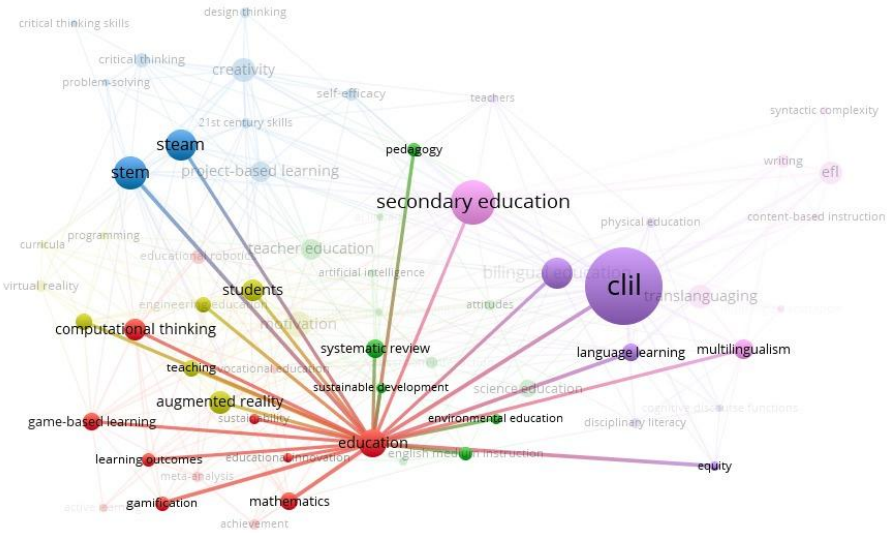


Figure 11. Visualization of keyword network focusses on education

Strongly linked to keywords education such as curriculum, engineering education, and educational computing. This indicates that STEAM research is largely directed at curriculum development and technology-based learning with a focus on secondary-level students support by CLIL.

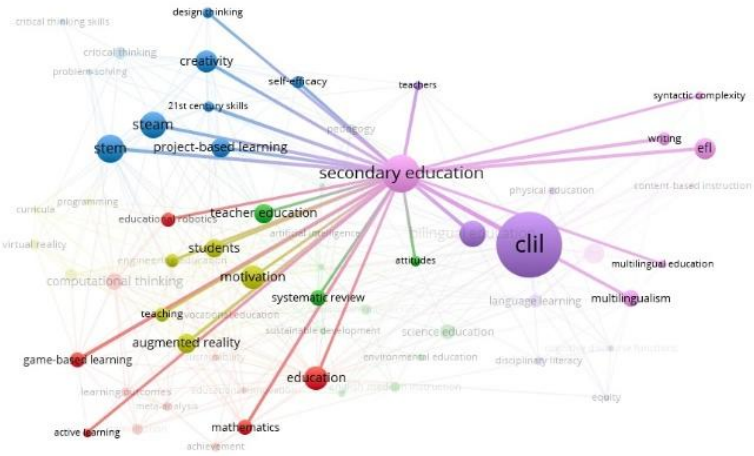


Figure 12. Visualization of keyword network focusses on secondary education

Strongly linked to keywords secondary education such as STEM, project-based learning, creativity, critical thinking, and 21st-century skills, confirming the research's orientation toward developing 21st-century skills. This indicates that STEM and CLIL research is largely directed at curriculum development with project-based learning focus for motivation on secondary-level students.

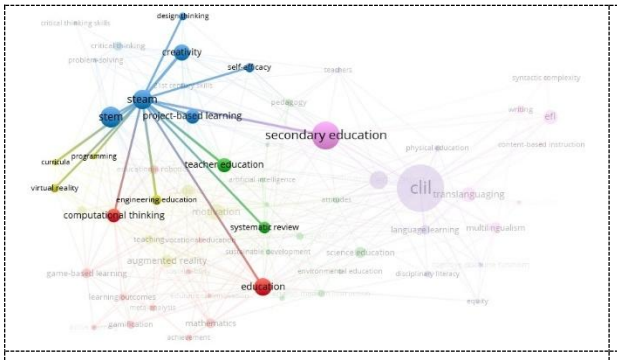


Figure 13. Justify the Caption.

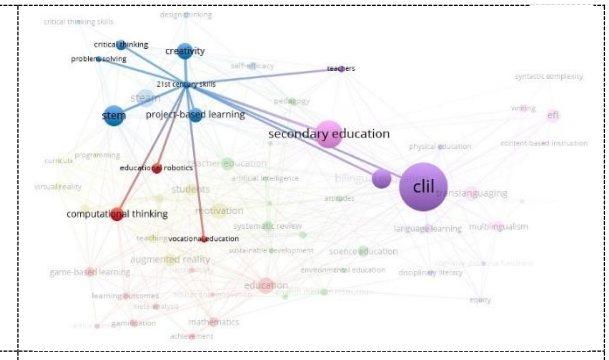


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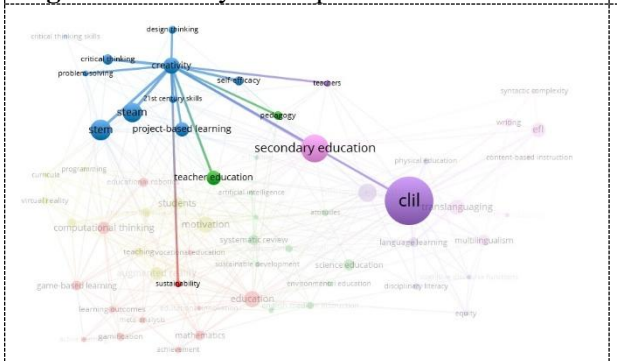


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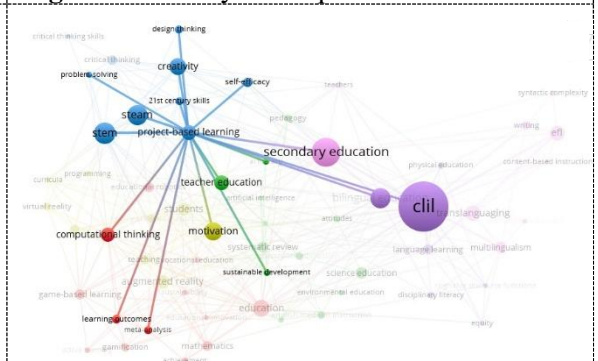


Figure 16. Justify the Caption.

Figure 13 until Figure 16 shows that the focus keywords STEAM, 21st-century skills, creativity, and project-based learning form a strong and interconnected network of links in the context of secondary education. The visualization shows that STEAM functions as a central conceptual node that integrates cross-disciplinary approaches in science, technology, engineering, art, and mathematics, while also serving as a foundation for the development of 21st-century skills. The close relationship with project-based learning confirms that STEAM implementation is generally realized through project-based learning that encourages active student involvement in authentic problem-solving. Furthermore, the emergence of the keyword creativity directly linked to STEAM and 21st-century skills indicates that creativity is seen as a key achievement in STEAM learning, in line with current research views that place creativity, critical thinking, collaboration, and communication as essential 21st-century competencies. This cross-cluster connection is also strengthened by the involvement of supporting keywords such as problem-solving, computational thinking, and innovation, indicating that STEAM research is oriented not only towards content mastery but also towards the development of higher-order thinking skills.

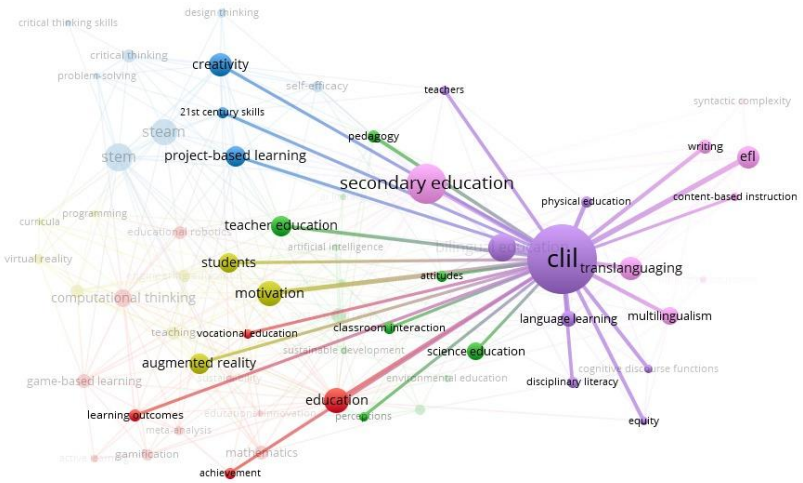


Figure 17. Visualization of keyword network

Figure 17 shows the keyword network visualization and shows the thematic structure of CLIL and STEAM research in the context of secondary education. Secondary education serves as the primary connecting node linking the various research clusters. The CLIL cluster is characterized by the dominance of the keywords CLIL, translanguaging, bilingual education, multilingualism, and language learning, reflecting a strong focus on integrating language learning and academic content. Meanwhile, the STEAM cluster focuses on the keywords STEM, project-based learning, creativity, critical thinking, and 21st-century skills, confirming the research's orientation toward developing 21st-century skills. Furthermore, the general education cluster, highlighted in red, displays connections with keywords such as education, mathematics, learning outcomes, gamification, and augmented reality, demonstrating the use of technology and innovative approaches in learning. These interconnections between clusters indicate that current research tends to integrate CLIL approaches with STEAM and technology-based pedagogical innovations to improve the quality of learning in secondary education.

Discussion

This research demonstrates that the conceptual link between CLIL and STEAM learning approaches is interconnected and has been examined in published Scopus research, particularly in secondary education contexts worldwide. The identified bibliometric trend analysis confirms that CLIL and STEAM have emerged as related topics, but no direct study of the combined implementation of CLIL and STEAM has been conducted. However, both CLIL and STEAM approaches are closely linked to the concepts of 21st-century education, creativity, curriculum, and learning technology, reflecting the global focus on interdisciplinary approaches to content and language learning. This aligns with conceptual studies showing that STEAM is not simply an extension of STEM but emphasizes the integration of arts and humanities, strengthening conceptual and reflective learning contexts (Perignat & Katz-Buonincontro, 2020).

The bibliometric findings also indicate that CLIL topics, when mapped to their meaning and role in literature, are consistently associated with themes of bilingual education, foreign language learning, learning motivation, and academic literacy. The theoretical aspect of CLIL focuses on its approach, which integrates language and academic content (Kaiypova et al., 2024). These results align with a recent meta-analysis, which revealed that while CLIL's effectiveness on mastering non-language content sometimes varies, its use still contributes to the bilingual and contextual learning of complex disciplinary content.

STEAM, on the other hand, has emerged as a pedagogical approach that emphasizes the integration of disciplines, including science, technology, engineering, arts, and mathematics, through project-based learning and authentic problem-solving, thereby fostering students' analytical, creative, and collaborative thinking skills (Perignat & Katz-Buonincontro, 2020). The integration of arts and humanities aspects into STEAM has been substantially identified as a mechanism that expands students' reflective and complex thinking skills in a contextual and meaningful manner. This strengthens the argument that STEAM contributes to the learning experience.

The interconnectedness of these two clusters in the literature indicates that CLIL and STEAM are increasingly discussed together through learning concepts such as project-based learning and inquiry-based learning, which serve as a methodological bridge between language and content development. Project-based approaches provide a concrete context for students to apply language competencies in complex, interdisciplinary STEAM learning situations, while fostering 21st-century skills such as creativity, collaboration, communication, and critical thinking (Perignat & Katz-Buonincontro, 2020).

The geographical distribution of the analyzed publications indicates that the CLIL–STEAM topic is not limited to a single region but spans a wide range of countries and educational contexts, indicating global attention to the implementation of this integrated pedagogy. The focus of research in regions with strong bilingual education, such as several European countries, and the increasing contributions from Asia and the Americas, reflect the increasing relevance of language and science integration in learning in preparing students to face global challenges in the 21st century. The bibliometric approach used in this study proved effective in mapping the research landscape and identifying trends or emerging areas, including the relationship between CLIL and STEAM.

These findings demonstrate a paradigm shift in secondary education, increasingly moving toward a coherently integrated learning approach across science, technology, the arts, and language. The bibliometric approach used in this study proved effective in mapping the research landscape and identifying emerging trends or areas, including the relationship between CLIL and STEAM. Visualization techniques such as co-occurrence analysis helped identify dominant literature clusters and potential relationships between themes that may have been less apparent in traditional literature reviews (Donthu et al., 2021).

CONCLUSION

This study reveals that the research landscape on CLIL and STEAM is dominated by a strong connection between the two approaches in the context of secondary education. Regarding dominant topic trends, the bibliometric analysis shows that CLIL and STEAM are central topics connected to the clusters of 21st-century education, creativity, curriculum, learning technology, and bilingual education. STEAM tends to be associated with the development of creativity and project-based learning, while CLIL forms a separate cluster closely related to language learning, bilingual education, and learning motivation.

The connection between the two clusters through concepts such as project-based learning marks the increasing convergence between science education and language learning. In terms of conceptual linkage and integration patterns, the results demonstrate that Project-Based Learning (PBL) and inquiry-based approaches serve as the primary methodological bridge between the two clusters. This integration pattern reveals that PBL provides the concrete context for applying language competencies (CLIL) within complex, interdisciplinary scenarios (STEAM). Consequently, while direct studies on the combined implementation remain an emerging field, the existing literature confirms a convergence of science education and language learning. These findings highlight a critical opportunity for future research to develop innovative, integrated STEAM–CLIL models that simultaneously foster scientific literacy and foreign language proficiency These findings confirm the shift in research towards an integrated STEAM–CLIL approach and open up opportunities for the development of innovative learning models that integrate science, technology, and language in an interdisciplinary manner in the future.

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