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Windows of Insight: A Review on Stained Glass Research Trends

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ABSTRACT

This study uses Scopus data from 1855 to 2023 to examine key trends and developments in stained glass research, showing a notable increase in academic work after 2000. This growth is linked to advances in digital technology and wider global access, allowing for interdisciplinary research combining materials science, engineering, and cultural studies. New technologies, such as hyperspectral imaging and laser cleaning, have significantly improved conservation methods. The study also shows an increasing contribution from the United States, alongside the continued leadership of Europe, with more diverse sources of funding reflecting global investment in stained glass research. By offering a comprehensive, long-term analysis, this review fills gaps in previous studies by addressing the lack of integrated research across different fields and regions. It provides useful insights for future research, policy-making, and conservation efforts, highlighting the global importance of stained glass. The findings emphasize its continuing relevance to art, technology, and cultural heritage preservation.

Keywords: Stained glass, bibliography analysis, interdisciplinary research, history, scopus

1. Introduction

In recent years, the stained-glass industry has seen notable growth and is expected to maintain this positive trend in the foreseeable future. According to recent data, the global stained-glass market was valued at $4.1 billion in 2022 and is forecasted to reach $6.8 billion by 2032, with a compound annual growth rate (CAGR) of 5.3% from 2023 to 2032 (David Correa, 2024).

Nevertheless, despite these promising trends, the stained-glass market faces formidable challenges. These include high labor and material costs, constraints related to market size, concerns regarding maintenance and durability, the necessity for specialized skills, competition from alternative materials, cultural shifts and economic factors (Verified Market Research, 2024).

Despite positive growth projections, the stained-glass industry faces significant challenges, particularly due to high labor and material costs. The industry is dealing with a shortage of skilled artisans, as many retire or move to other fields (Precedence Research, 2024; Mulligan, 2023). Additionally, material costs have risen sharply, especially for high-quality colored glass. For instance, the price of some mouthblown glass sheets has increased by 50% in just three years, influenced by factors such as Brexit-related import fees and rising energy costs in manufacturing (Mulligan, 2023). The industry also faces competition from alternative materials, changing cultural trends, and economic pressures (Verified Market Research, 2024).

Stained glass carries deep cultural and heritage significance, extending beyond its economic value by representing historical artistry, craftsmanship, and serving as a medium for cultural stories and religious symbolism. Referred to as a "monumental art of importance" (Allen, 2012), stained glass offers insights into the beliefs, aesthetics, and craftsmanship of past periods, often acting as "visual sermons" that have educated and inspired audiences for centuries (Raguin, 2013). Stained glass windows, such as those in York Minster,

not only illustrate important historical figures and events but also function as visual records, enhancing our understanding of cultural heritage (Brown, 2017). Conserving stained glass is crucial, not only for its artistic value but also for preserving the architectural integrity and atmosphere of historic buildings. Modern technologies are playing a key role in these conservation efforts, as seen in the restoration of Notre Dame Cathedral following the 2019 fire. Techniques like hyperspectral imaging and Raman spectroscopy have been used to analyze the glass composition, allowing conservators to detect microscopic damage that is invisible to the naked eye and make informed restoration choices. This innovative approach highlights the importance of combining traditional craftsmanship with advanced scientific research to preserve these culturally important artifacts (Wais-Wolf et al., 2022). Ultimately, the preservation of stained glass protects both tangible and intangible cultural heritage for future generations, while also supporting ongoing research into historical materials and techniques (Corpus Vitrearum, 2004).

To support the preservation of the distinctive artistic and cultural values inherent in stained glass works, conducting a thorough review of its development is essential. Various aspects of stained-glass review have reported across disciplines. Although various aspects of stained glass have been examined across disciplines, such as its historical and cultural significance (Allen, 2012), material science and technological advancements (Maingi et al., 2022; Trümpler et al., 2012), art historical value (Cothren, 2012; Wais-Wolf et al., 2022) and conservation methods (Bernardi et al., 2013; Patin et al., 2022), no study has systematically reviewed the scholarly discourse over time. Specifically, there is a lack of research examining the patterns and trends in academic publications on stained glass. This gap limits our understanding of how the research field has evolved and highlights areas that may require further investigation or support.

In this study, we analyzed the publication trend of stained-glass using data from Scopus and reported our findings. The methodology involved several key steps to ensure a comprehensive examination of the research landscape. First, we defined specific criteria for selecting relevant publications, which included searching for articles, reviews, and conference papers that contained the keywords "stained glass" in their titles, abstracts, or keywords. The search was further refined by setting a specific timeframe to capture both historical and contemporary research trends. Only peer-reviewed publications were included to ensure the reliability of the data. Once the dataset was compiled, we employed quantitative analytical techniques to examine the number of publications over time, identifying patterns of growth or decline in research activity. Additionally, we performed a thematic analysis by categorizing publications based on subject matter and keywords to identify key themes and prominent research topics within the stained glass domain. To enhance the analysis, we also tracked the contributions of leading affiliations and countries to map out the global distribution and influence of stained glass research. The combination of these techniques allowed us to provide a detailed overview of the research landscape, highlighting emerging trends and areas in need of further exploration.

This analysis holds significant importance for several reasons. Firstly, it offers valuable insights into the current state and dynamics of research in the field of Stained Glass. By examining the number of publications over time, we can identify patterns, trends and areas of growth or decline. Such information can guide future research directions and priorities, assisting researchers in focusing their efforts on topics gaining traction or needing further exploration. For instance, identifying under-researched areas can open new avenues for academic inquiry and encourage interdisciplinary collaborations that might not have been previously considered. Secondly, the analysis can highlight key themes and topics within the stained glass research domain. By categorizing publications based on subject matter or keywords, we can identify prominent areas of interest and leading contributors to the field. This aids researchers in identifying potential collaborators, tracking the influence of specific research groups or institutions, and assessing the impact of different research themes on overall knowledge. Importantly, this insight into scholarly influence can foster strategic partnerships across institutions, helping to pool resources and expertise for more significant advances in stained glass research and preservation.

Moreover, the findings have practical applications for stakeholders beyond academia. Analyzing publication trends can provide policymakers and cultural institutions with data-driven insights that can inform decisions regarding funding priorities, conservation strategies, and educational initiatives. For industry professionals, understanding shifts in research focus can inform innovation in materials, restoration techniques, or public engagement initiatives. Additionally, the identification of emerging themes or growing areas of interest may inspire new commercial opportunities, such as the development of advanced conservation materials or the promotion of stained-glass heritage tourism. Overall, this study’s findings offer a roadmap for shaping the future of stained-glass research and ensuring that preservation efforts remain aligned with both scholarly and societal needs.

2. Research Design

Our analysis delved into the publication trend of stained glass, spanning the entire collection of the Scopus database from 1855 onwards. We chose to initiate our examination from this year, as it marked the earliest relevant publication discovered in the Scopus database. Although Scopus began its indexing more recently, the platform retroactively includes older works through digitization and collaborations with publishers, allowing us to capture historically significant studies. The first article found in 1855 represents the earliest recorded scholarly contribution to the field within Scopus, making it a suitable starting point for our analysis. By including this early publication, we ensure that our review encompasses the full historical scope of research on stained glass, providing a comprehensive understanding of the field's evolution from its earliest academic discussions to the present. Although it is not possible to make statistical generalisations about the sample being studied, we can make analytical generalisations about the trends of stained glass by exploring the entire data sources. More specifically, this study can provide a comprehensive whole picture about the trends of stained glass in terms of related during the study period (i.e. 1855–2023). More detail explanations about the analysis approach are provided in the following sections.

Scopus is a comprehensive abstract and citation database that covers a wide range of scientific, technical, medical and social sciences literature. According to the information provided by Scopus (https://www.elsevier.com/products/scopus/content), it provides access to an extensive range of academic resources, encompassing over 29.2 thousand journals, collaborations with over 7 thousand publishers, a catalog boasting 330 thousand books and a staggering collection of over 23.4 million open access items. Its repository holds a wealth of 94 million records, while its archive contains an impressive 2.4 billion cited references dating back to 1970. Furthermore, researchers benefit from comprehensive author profiles totalling over 19.6 million and more than 99.6 thousand affiliation profiles, facilitating the tracking of publication history and scholarly impact.

Scopus offers extensive coverage of scholarly literature across various disciplines (Putra et al., 2023), updated bibliometric analysis capabilities (Dawit Negussie Tolossa et al., 2023) and comprehensive indexing features that support effective trend analysis and citation tracking (Subeesh V.K. & M.A. Joseph, 2023). In summary, Scopus was chosen for this study due to its robust citation tracking and bibliometric analysis capabilities, which directly support the analysis of publication trends. Its comprehensive indexing across multiple disciplines allows for effective identification of research patterns over time, making it an ideal platform for conducting a thorough review of stained glass literature. These features ensure accurate trend analysis and provide valuable insights into the scholarly impact and evolution of the field.

Based on the collected data from Scopus, we reviewed the publication trends from eight different perspectives, employing specific methodologies and analytical tools to ensure consistency and accuracy. The following outlines the approach taken for each perspective:

I. Publication trend: We quantified the evolution of stained glass research by analyzing the number of publications over time, using annual publication counts as a metric. Time-series visualizations were created to identify patterns of growth, stagnation, or decline. Statistical techniques, such as linear regression and moving averages, were applied to detect significant trends.

II. Documents by affiliations: Institutional contributions were categorized by affiliation data from each publication. We quantified the number of publications per institution and analyzed collaborative networks using co-authorship data. Network analysis techniques were employed to visualize and interpret the collaboration patterns among different institutions and organizations.

III. Documents by country or territory: The geographical distribution of research was examined by categorizing publications according to the country or territory of the authors. Geographic heat maps were used to highlight regions with higher concentrations of research activity. Additionally, trends in regional research contributions over time were analyzed to assess the global spread of stained glass research.

IV. Documents by language: Publications were categorized by language to determine linguistic trends in the dissemination of research. We calculated the proportion of publications in each language and analyzed how these proportions shifted over time, offering insights into the accessibility and reach of research across different linguistic communities.

V. Documents by funding sponsor: Funding sources for stained glass research were identified from the metadata of each publication. We categorized the documents by funding agencies and analyzed the impact of funding trends on research output. The analysis focused on identifying which institutions or countries received the most financial support and how funding influenced research productivity.

VI. Documents by document type: Publications were categorized by document type (e.g., journal

articles, reviews, conference papers) to provide an overview of the forms of scholarly output. We calculated the distribution of document types and analyzed how these evolved over time, helping to understand the scope and nature of scholarly contributions to the field.

VII. Documents by subject area: Publications were mapped to subject areas such as art history, materials science, architecture, and religious studies to assess the interdisciplinary nature of stained glass research. By quantifying the number of publications in each subject area, we identified the dominant fields contributing to stained glass research and explored emerging interdisciplinary connections.

VIII. Documents by keywords: We conducted a keyword analysis by extracting and categorizing the keywords from each publication. Using text-mining techniques, we identified the most frequently occurring keywords and performed trend analysis to detect emerging topics. Clustering techniques were employed to group related keywords and reveal key themes within the research landscape.

These eight perspectives are selected because we aim to provide more comprehensive and diverse views on the publication trends. Given the approach being used in this study is directly repeatable; therefore, the findings are transparent and reproducible. As per (Fisch & Block, 2018), transparent and reproducible are two key features of the systematic literature review in research. Moreover, similar approach has been applied in other studies (Leong et al., 2021, 2023; Liao et al., 2017; Samala et al., 2023; Wang & Chen, 2010).

3. Findings and Discussions

We conducted a search on Scopus using the terms "stained glass" or "stained-glass" in either the ‘Abstract’ or ‘Article Title’ fields. We specifically targeted the ‘Abstract’ and ‘Article Title’ fields, excluding the ‘Keywords’ field, due to the possibility of irrelevant publications being tagged with 'stained glass' under engineering-controlled terms. This focused search method aimed to ensure the accuracy of our findings.

The search was conducted in April 2024, covering data up to 2023 to provide a comprehensive review and facilitate meaningful comparisons. We chose this timeframe as the earliest relevant publication we found dated back to 1855, thus encompassing the period from 1855 to 2023.

Applying the aforementioned criteria, we initially identified 1208 documents. Subsequently, we refined our selection by excluding irrelevant publications, resulting in a final list of 1086 documents for our study. The excluded documents did not pertain to stained glass as intended for this research. For example, some documents mentioned 'stained glass' in the abstract within medical-related studies, but the term referred to a visual resemblance on CT scans rather than actual stained glass.

3.1. Publication trend

Figure 1 illustrates the publication trend of the 1,086 documents related to 'stained glass' on Scopus from 1855 to 2023. As seen in the figure, the publication trend for 'stained glass' can be distinctly divided into two periods: before and after the year 2000. Initially, from 1855 until the end of the 20th century, the number of documents related to stained glass remained relatively low, with minor fluctuations and a notable peak around 1915. After a period of modest growth starting in the 1960s, the trend remained gentle with publications gradually increasing as the century progressed.

A marked change occurred at the onset of the 21st century. Post-2000, there was a significant surge in the number of publications, with the curve rising steeply. This shows a heightened interest and activity in stained glass research or applications in the recent period, in contrast to the more stable and subdued trend seen in the previous years. The graph also reveals some recent variations in the number of documents year on year, yet the general direction of the trend continues to point upwards. In fact, the significant rise in stained glass-related publications after 2000 coincides with notable restoration projects, such as the ongoing conservation of the stained glass windows at the Notre Dame Cathedral in Paris. This project, initiated after the 2019 fire, has leveraged modern technologies like hyperspectral imaging and Raman spectroscopy, showcasing the integration of cutting-edge scientific techniques with traditional conservation methods.

In fact, selecting the year 2000 as the dividing point for analyzing the publication trend of documents related to stained glass on Scopus offers a clear and logical breakpoint for several reasons. Firstly, the year 2000 represents the start of a new millennium, symbolizing a shift in global consciousness and technological advancements. This milestone often marks a period of reflection and anticipation for the future, which can influence academic and research activities. Therefore, using the year 2000 as a dividing point acknowledges the broader socio-cultural context and the potential impact it may have had on research trends.

Secondly, the onset of the 21st century brought about significant changes in communication, particularly with the widespread adoption of the internet and digital technologies. These advancements facilitated easier access to information, increased collaboration among researchers and accelerated the pace of scientific

discovery. Consequently, research output in various fields, including stained glass, may have experienced a notable uptake post-2000 due to these technological advancements.

Moreover, the choice of the year 2000 as a dividing point allows for a convenient comparison between two distinct periods: the 20th century and the 21st century. By examining the publication trend before and after this pivotal year, significant shifts or patterns in scholarly activity related to stained glass can be identified.

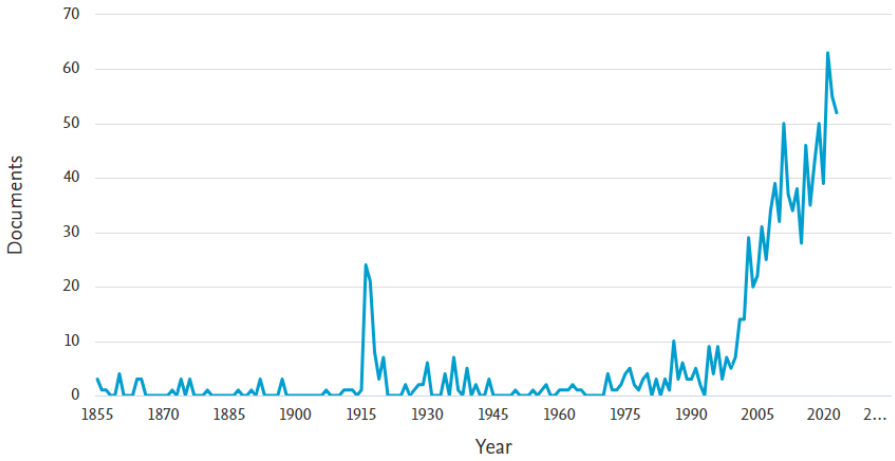

Figure 1. Publication trend of stained-glass related documents (image source: Scopus).

By dividing the entire period into two distinct periods based on the year 2000, we were able to conduct a more granular analysis of the publication trend related to stained glass. The data obtained revealed 249 documents for the pre-2000 era (1855-1999) and 837 documents for the post-2000 period (2000 to 2023). This division allowed for a focused examination of trends and patterns in stained glass research, facilitating a deeper understanding of the field's evolution over time.

In the subsequent sections, we delve into a comprehensive analysis of various perspectives, drawing insights from the pre- and post-2000 periods.

3.2. Documents by affiliations

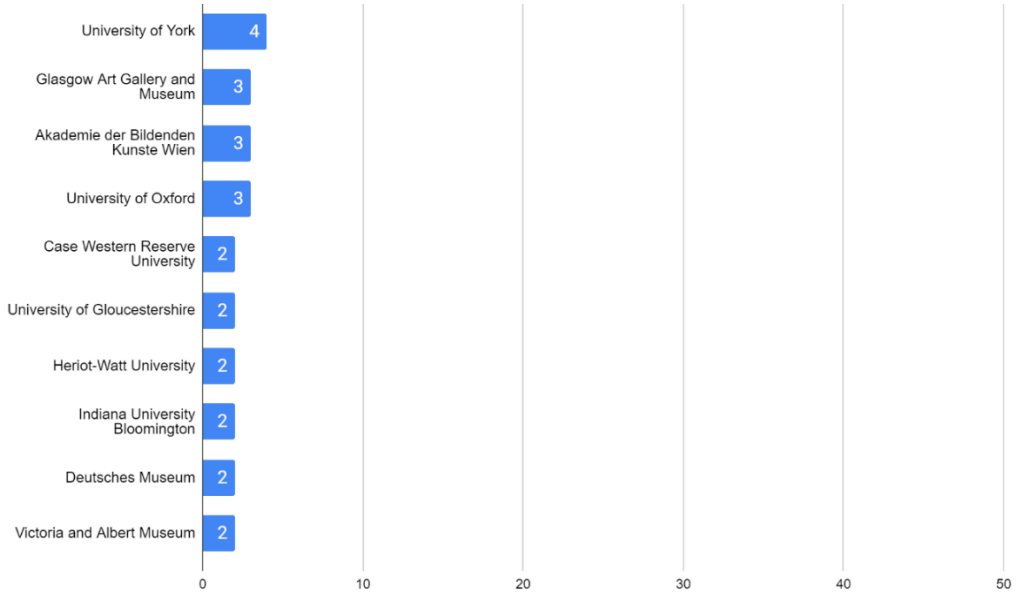

Figure 2. Documents by top 10 affiliations from 1855 to 1999

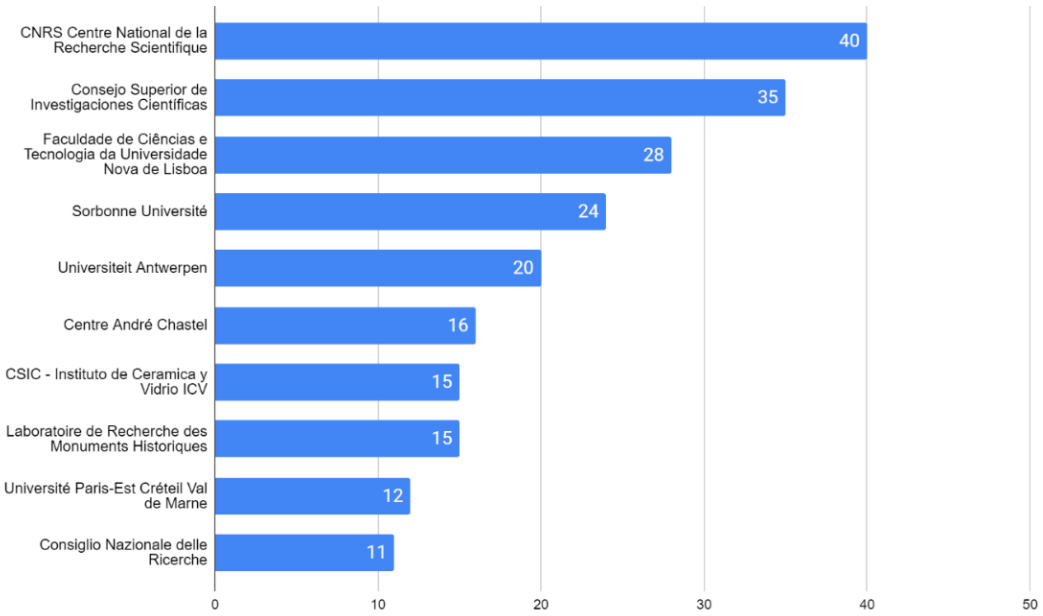

Figure 3. Documents by top 10 affiliations from 2000 to 2023

Figure 2 illustrates the number of stained glass-related documents produced by the top 10 institutions between 1855 and 1999. Most of these institutions are in Europe and the United States, indicating that these regions have a strong interest in stained glass research. The chart includes universities and museums, with the University of York producing the most documents.

The involvement of various academic institutions, like universities and cultural centers, such as museums and galleries, indicates that stained glass is a specialized but significant area of study. Although no single institution has a very high count of documents, the diversity suggests a broad and dedicated interest in the field. This research is important because it combines academic study with the practical work of preserving historical artifacts.

On the other hand, figure 3 shows how many documents on stained glass were produced by top research groups from 2000 to 2023. Most of these groups are in Europe, with the French National Centre for Scientific Research leading with 40 documents. This suggests that Europe is very active in stained glass research. Other European countries like Spain, Portugal, Belgium and Italy also contribute, showing a widespread European interest in this subject.

Compared to the previous century, there's a clear increase in research on stained glass, indicating that this field is gaining more attention. This may reflect a broader trend in Europe, where there's a rich history and many historical stained glass artifacts to study and preserve. These institutions are likely influencing how we look after and appreciate stained glass worldwide, using new research methods to better understand and care for this form of art.

Nevertheless, it is important to note that a forthcoming analysis, detailed in the following section, reveals that the majority of authors hail from the United States. This suggests that although European institutions are prominent in terms of output, American researchers play a significant role in the field.

3.3. Documents by country or territory

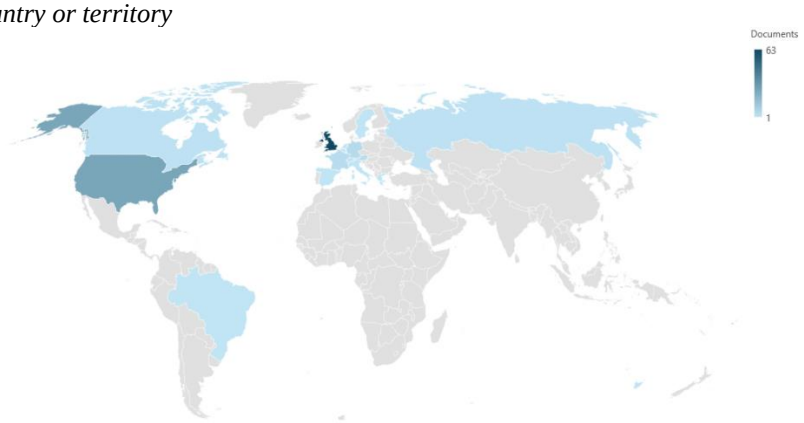

Figure 4. Documents by country or territory from 1855 to 1999

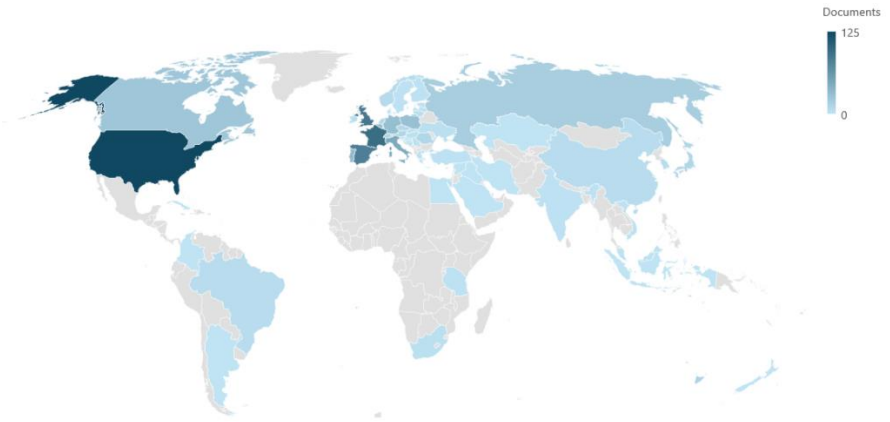

Figure 5. Documents by country or territory from 2000 to 2023

Figure 4 delineates the production of stained glass-related documents by various countries from 1855 to 1999. In terms of geographical distribution, the United Kingdom emerges as the foremost contributor, owing to its deep-rooted tradition in stained glass, especially prevalent in historical and religious edifices. This prominence may be attributed to a robust academic emphasis on art history and conservation within the country. Following closely is the United States, indicating a substantial involvement of American scholars on stained glass research, despite the fewer number of documents originating from U.S. institutions. Additionally, notable contributions come from Germany and Austria, reinforcing Europe's enduring association with stained glass, particularly concerning its historical significance in art and architecture.

From the global trends and perspectives, the concentration of stained-glass research in countries with strong historical ties to this art form suggests a correlation between the presence of stained glass works and the volume of academic inquiry they generate. This trend underscores a persistent global interest in the study of stained glass, driven by its cultural and artistic significance. Furthermore, the chart indicates a worldwide appreciation for the preservation and scholarly exploration of stained glass, transcending its geographical origins.

Overall, the data underscores a pronounced European focus in stained glass research, highlighting the pivotal role of countries like the UK and the United States as stewards of this cherished art form during the period pre-2000.

Figure 5 illustrates the quantity of documents related to "stained glass" by the top 10 countries from 2000 to 2023. In this recent period, the United States has emerged as the foremost producer of stained-glass documents, marking a significant shift from previous years where the United Kingdom held the lead. France continues to be a major contributor, consistent with its long-standing interest in art and heritage conservation. While the United Kingdom still maintains a strong presence, it has been surpassed by both the United States and France during this timeframe, indicating changes in research activity or investment in stained glass studies.

There's a noticeable expansion in the geographical diversity of countries involved in stained glass research. Countries like Spain, Italy and Portugal demonstrate robust participation, reflecting a growing acknowledgment of cultural heritage significance in these regions. The rise in documents from North America (the United States and Canada) and the inclusion of Poland suggest that stained glass research is becoming more global, extending interests beyond Europe. In fact, it is worth noting that an expansion in the global reach of stained-glass research, with documents coming from 24 countries, up from 16 in the previous period of 1855 to 1999. This increase reflects a more diverse and widespread interest in stained glass as a subject of academic and cultural significance.

The geographical distribution has become more inclusive, indicating that the field of stained-glass research has gained traction in a wider array of countries. The growth from 16 to 24 countries involved in publishing-stained glass documents suggests the emergence of new research centers and academic programs around the world. It also hints at an increase in international collaboration, possibly driven by global conservation efforts, technological advancement and a shared recognition of the value of stained glass in cultural heritage.

The presence of the United States at the top of the list during 2000 to 2023, surpassing the historically leading UK, signals a shift in where the leading research and discussions are taking place. European countries, with their rich traditions of stained glass, maintain strong contributions, but the addition of more countries, including those without a long-standing tradition of stained glass related publications, suggests that the appeal and relevance of stained-glass studies have broadened significantly.

This expansion indicates that the study of stained glass is now not limited to regions with the most significant historical collections; it has evolved into a global field with contributions from around the world. This could result in broader research perspectives, encompassing various conservation techniques,

interpretations and applications of stained glass in contemporary architecture and art. Indeed, this perspective aligns with the findings from the analysis of subject areas and keywords, which will be discussed in later sections.

In overall, the comparison between the two time periods underscores dynamic changes in the academic landscape, with countries like Poland and Canada entering the top ranks, indicating new or expanding research initiatives in these regions. Overall, the comparison highlights a significant shift in global research dynamics, suggesting a vibrant global community dedicated to the preservation and study of stained glass, transcending regional and historical boundaries.

3.4. Documents by language

Table 1. Language of Publication with more than or equal to 3 times from 1855 to 1999.

Language	Counts
English	234
French	4
German	3
Spanish	3
Swedish	3

Table 2. Language of Publication with more than or equal to 3 times from 2000 to 2023.

Language	Counts
English	689
French	61
Spanish	35
Italian	15
Russian	7
German	6
Lithuanian	6
Dutch	5
Japanese	5
Polish	5
Czech	3

The expansion of countries engaged in stained glass research is also reflected in the languages used in publications.

Table 1 displays the languages of publication occurring three times or more from 1855 to 1999. According to the findings, apart from six publications with unidentified languages, a total of eight languages were identified during this period. Additionally, Dutch, Italian and Russian each appeared once but are not listed in the table. English emerges as the predominant language, making up 91.4% of publications.

Table 2 presents the languages of publication occurring three times or more from 2000 to 2023. Apart from one publication with an unidentified language, a total of 24 languages were identified during this period. English remains the primary language, comprising 80.5% of overall publications. However, there is a noticeable increase in the use of other languages during this period. The diversification of languages used in stained glass research publications from 1855 to 2023 suggests several potential implications and insights.

Firstly, the increase in the number of languages used in publications reflects a broader global engagement with stained glass research. As more countries participate in scholarly discourse on stained glass, it indicates a growing interest and appreciation for this art form worldwide. Consistent with earlier findings, this increase in languages may also indicate the inclusion of diverse cultural viewpoints and methods into stained glass studies, enhancing the field with a wider range of perspectives and approaches.

Secondly, the dominance of English as the primary language of publication highlights its role as a lingua franca in academic communication. English proficiency among researchers and scholars across the globe facilitates the dissemination of knowledge and fosters collaboration in the field of stained glass research.

However, the significant increase in the use of other languages alongside English suggests a recognition of the importance of language diversity in scholarly discourse. This trend may encourage greater inclusivity and accessibility within the stained glass research community, allowing researchers to engage with and contribute to the field in their native languages.

Furthermore, the identification of previously overlooked languages such as Dutch, Italian and Russian in stained glass research publications underscores the need for a more comprehensive and inclusive approach to documenting and analyzing scholarly output. Understanding the linguistic diversity of stained glass research publications can provide valuable insights into the global distribution of knowledge production and the cultural contexts shaping scholarly inquiry in different regions. This recognition of linguistic diversity may also prompt efforts to improve language representation and translation services within the academic community, ensuring that research findings are accessible to a broader audience and facilitating cross-cultural exchange and collaboration.

3.5. Documents by funding sponsor

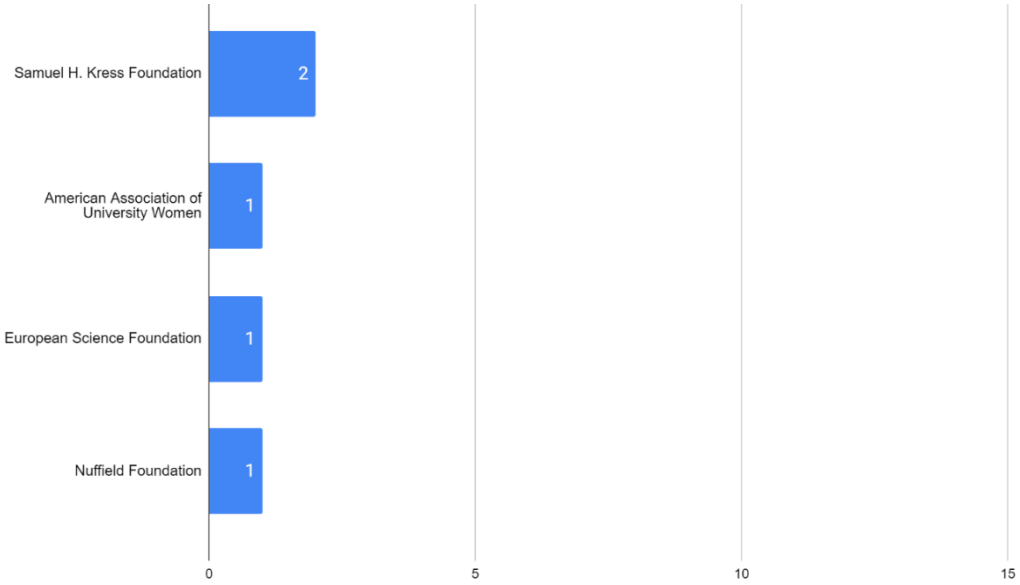

Figure 6. Documents by funding sponsor from 1855 to 1999

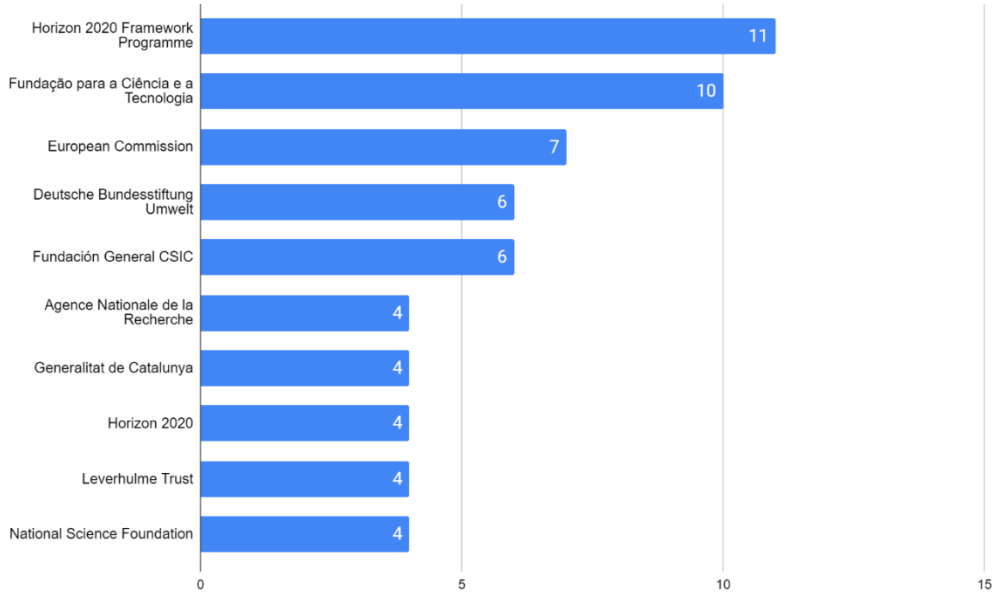

Figure 7. Documents by funding sponsor from 2000 to 2023

Figure 6 illustrates the number of documents related to stained glass that received funding from various sponsors between 1855 and 1999. Several implications can be drawn from this chart and related to the trends observed in the earlier provided data on the geographical distribution of stained glass documents.

The Samuel H. Kress Foundation emerges as the leading sponsor with two documents. Known for its

support of art history and preservation studies, this foundation's involvement aligns with the trends indicating a historical emphasis on stained glass research, particularly from European and American institutions. Other sponsors such as the American Association of University Women, the European Science Foundation and the Nuffield Foundation, each with one document, suggest that funding for stained glass research comes from organizations with broader academic and scientific interests beyond art specialization.

Figure 7 illustrates the number of documents related to stained glass funded by various sponsors from 2000 to 2023. This period shows a notable increase in funding sponsors and a higher number of funded publications compared to the earlier era (1855-1999).

According to the finding, there is a significant expansion in the range of sponsors, with entities like the Horizon 2020 Framework Programme and Fundação para a Ciência e a Tecnologia taking the lead. This indicates a heightened interest and investment in stained glass research, aligning with the global increase in research output from various countries. The presence of multiple sponsors from different regions, particularly European entities such as the European Commission and the Deutsche Bundesstiftung Umwelt, reflects the continent's dedication to cultural heritage and scientific research.

On the other hand, the diversity of sponsors, ranging from government bodies to private trusts like the Leverhulme Trust and international programs, signifies a broader acknowledgment of the importance of stained-glass research across various funding landscapes.

Moreover, the increase in funded publications suggests a growing academic interest and likely expansion of research capacity in stained glass studies. It indicates a greater recognition of the necessity for scholarly work in this area, potentially leading to more substantial funding opportunities. The rise in publications could also be linked to technological advancements in research methodologies, which may require and attract more funding. In addition, the higher number of publications may further indicate that the outcomes of this research are valued as significant contributions to the understanding and preservation of cultural heritage.

This finding supports the trend observed in the increase in the number of countries contributing to stained glass research. A broader array of sponsors implies that the research is not only more global in its academic participation but also in its financial support.

The involvement of the National Science Foundation, a major U.S. funding agency, aligns with the earlier observation that the United States has become a prominent player in stained glass research during this period. The continuation of European entities as significant sponsors echoes the earlier trend of a strong European emphasis in stained glass studies, supported by robust funding streams.

In summary, the data from 2000 to 2023 shows a marked increase in both the number of funding sponsors and funded publications in the field of stained-glass research. This aligns with the trend of stained glass becoming a more globally recognized field, attracting a diverse set of funding sources. It also reflects the broader geographical spread of research contributions, indicating a wider appreciation for stained glass studies and their importance in cultural heritage across the globe. The increased investment in this research highlights the growing importance placed on understanding and preserving the art and history of stained glass.

3.6. Documents by type

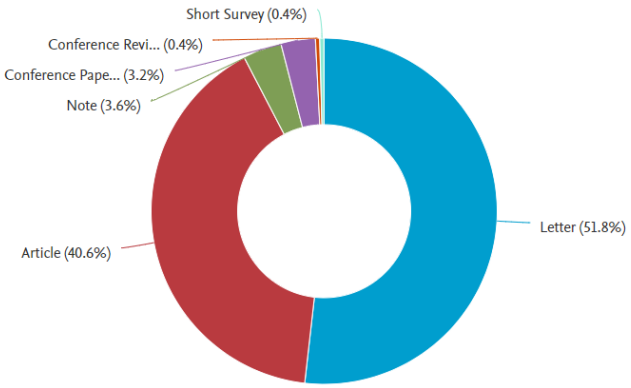

Figure 8. Documents by type from 1855 to 1999 (image source: Scopus)

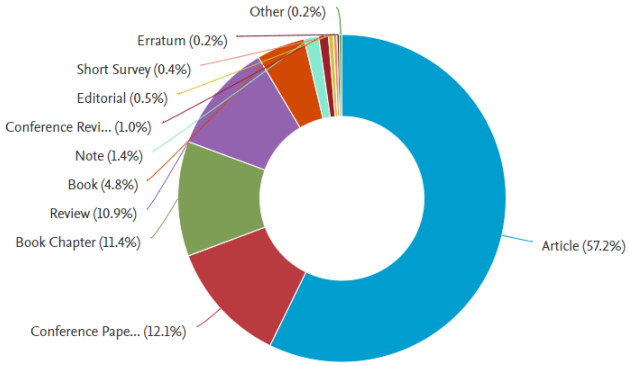

Figure 9. Documents by type from 2000 to 2023 (image source: Scopus)

As per figure 8, the most common type of documents from 1855 to 1999 were letters, which make up more than half and articles, which are about 40%. In the Scopus context, the document type "letter" typically refers to short articles written by experts or researchers in a particular field addressing issues or concerns. Letters are usually brief and serve as a means for scholarly discussion and communication within the academic community.

Other documents like conference papers, notes and surveys were also part of the mix but in much smaller numbers. This tells us that these were less preferred ways of sharing information.

Figure 9 shows the distribution of stained glass documents from 2000 to 2023. A striking change from the previous period is the apparent disappearance of "Letters" as a category. In the earlier dataset from 1855 to 1999, "Letters" accounted for a significant majority, but they no longer appear as a significant document type in the latest period. This could suggest a substantial shift in academic practices within the field.

Articles remain the key platform for sharing information, with a notable 57.2% of the documents, underscoring the continued importance of formal publication in academic discourse. In comparison to the previous period, the diversity in document types and the significant representation of conference papers could imply that the field has become more collaborative and international, with a greater emphasis on sharing knowledge in varied academic forums. Additionally, the increase in formal reviews and book chapters could imply a shift toward consolidating knowledge and offering critical evaluations of the field's progression. Moreover, the introduction of categories like "Errata" and "Editorials," though small in percentage, highlights the dynamic nature of scholarly communication, where ongoing dialogue and corrections are essential for the development of knowledge.

This trend reflects the scholarly evolution within the stained glass field, adapting to new academic norms and technologies in the 21st century. The finding underscores the importance of a multi-faceted approach to research dissemination, highlighting the need for researchers to engage with a variety of document types to gain a comprehensive understanding of the field.

Although analyzing document types alone provides valuable insights into the nature and format of publications, it may not fully capture the nuances of the academic publishing landscape. Understanding the subject area alongside document types adds depth to the analysis by providing insights into the specific areas where the research is disseminated. In the following section, we present the findings from our analysis of subject area.

3.7. Documents by subject area

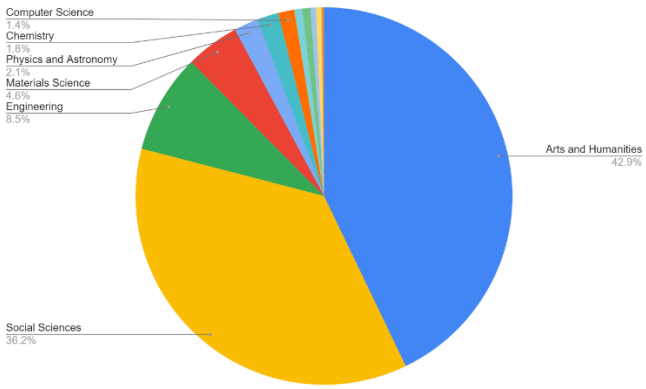

Figure 10: Documents by subject area from 1855 to 1999

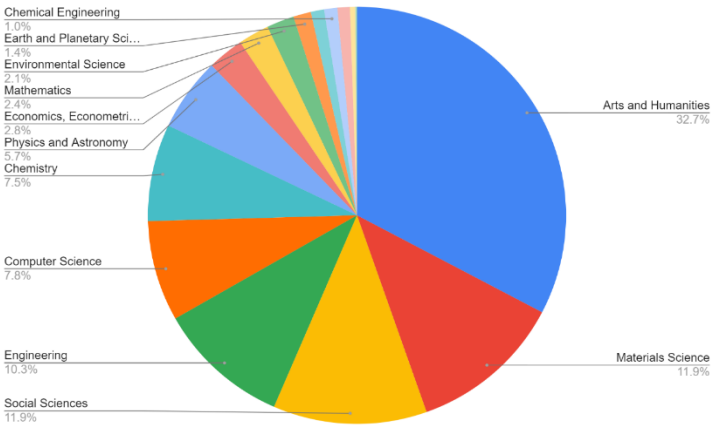

Figure 11. Documents by subject area from 2000 to 2023

Figure 10 provides a breakdown of the distribution of publications in the field of stained glass from 1855 to 1999, across various academic disciplines. The largest segment of the chart is occupied by "Arts and Humanities," representing 42.9% of the total publications. This dominance is expected as stained glass is traditionally associated with artistic expression and historical significance. The "Social Sciences" also constitute a large portion, at 36.2%, indicating substantial interest in the cultural, historical, sociological and perhaps anthropological aspects of stained glass.

The remaining slices of the pie chart represent scientific and technical disciplines with smaller percentages. "Engineering" accounts for 8.5% of publications, which may include studies on the structural integrity of stained glass, as well as its restoration and preservation techniques. "Materials Science" at 4.6% could reflect research into the composition and degradation of glass materials, while "Physics and Astronomy" and "Chemistry" have smaller shares at 2.1% and 1.8% respectively, possibly covering the physical properties of glass and chemical processes involved in glass coloring and deterioration.

The presence of "Computer Science" with 1.4% is quite interesting, suggesting that even during this period, there was an emerging interest in utilizing computing for analysis, design or restoration of stained glass.

The implications of this distribution are multifold. Firstly, the study of stained glass is inherently interdisciplinary, bridging arts and humanities with social sciences and applied sciences. This indicates a rich tapestry of research approaches, from theoretical to practical applications. In addition, the significant share of social sciences highlights the role of stained glass in society and its influence on various aspects of cultural heritage and social identity. Moreover, the slice for engineering and materials science points to the technical challenges faced in the preservation of stained glass and the need for ongoing innovation in these fields.

Overall, the data suggests that while stained glass is rooted in the arts and humanities, its significance spans across various disciplines, reflecting its multifaceted nature and the diverse approaches to its study and preservation. The relatively small but notable inclusion of technical and scientific fields points towards a holistic view of stained glass that encompasses creation, conservation and study within both cultural and scientific paradigms.

In addition, figure 11 shows a distribution of publications in the field of stained glass for the period 2000 to 2023 across several academic disciplines. Compared to the earlier period of 1855 to 1999, "Arts and Humanities" remains the largest category but has a reduced percentage, accounting for 32.7% of publications. This suggests a continued emphasis on the artistic and historical aspects of stained glass, though there is a noticeable diversification into other fields.

Notably, "Materials Science" and "Engineering" have become significant areas of focus, with 11.9% and 10.3% respectively. This increase points towards a growing interest in the physical and technical aspects of stained glass, such as the materials used, their durability and the methods of preserving and restoring stained glass works. "Computer Science" has also seen a substantial rise to 7.8%, potentially reflecting the use of digital technologies in the analysis, visualization and restoration of stained glass.

"Social Sciences" remains a considerable category at 11.9%, indicating that stained glass continues to be a subject of interest in terms of its impact on society, culture and possibly its socio-economic aspects. Other scientific disciplines, such as "Chemistry," "Physics and Astronomy," and "Environmental Science," maintain a presence, suggesting interdisciplinary research that encompasses the chemical processes of glass making, the physical properties of light and color and environmental impacts on stained glass conservation.

Comparing this with the distribution from 1855 to 1999, there is a clear shift from a dominant focus on arts

and humanities to a more balanced approach that includes considerable contributions from technical and scientific disciplines. This may reflect changes in the field's priorities, such as an increased emphasis on preservation techniques and the application of new technologies in the study of stained glass.

Overall, the distribution from 2000 to 2023 suggests a field that is expanding beyond its traditional boundaries to incorporate scientific research and cutting-edge technology, possibly driven by new challenges in conservation and a desire to understand stained glass in more depth. This interdisciplinary approach may lead to innovative methods for preserving stained glass, ensuring its enjoyment and study for future generations. In fact, the use of stained glass is not limited to historic preservation but has found applications in contemporary architecture. A prime example is the Chapel of St. Ignatius at Seattle University, where architect Steven Holl integrated stained glass to create a dynamic interplay of light and space. This case illustrates how modern architects are incorporating stained glass into cutting-edge designs, further expanding its interdisciplinary appeal.

In recent decades, the resurgence of stained glass research, particularly in the fields of materials science and engineering, reflects broader socio-cultural dynamics. The preservation of historic stained glass windows is not merely a technical conservation effort; it embodies society's desire to maintain a tangible link to its cultural and religious heritage. Additionally, the revival of stained glass as an artistic medium in contemporary architecture highlights a renewed appreciation for craftsmanship and the symbolic power of visual storytelling. As nations seek to preserve and celebrate their cultural identities, stained glass, with its rich historical significance, has become a central focus of heritage conservation and a source of national pride.

3.8. Documents by keywords

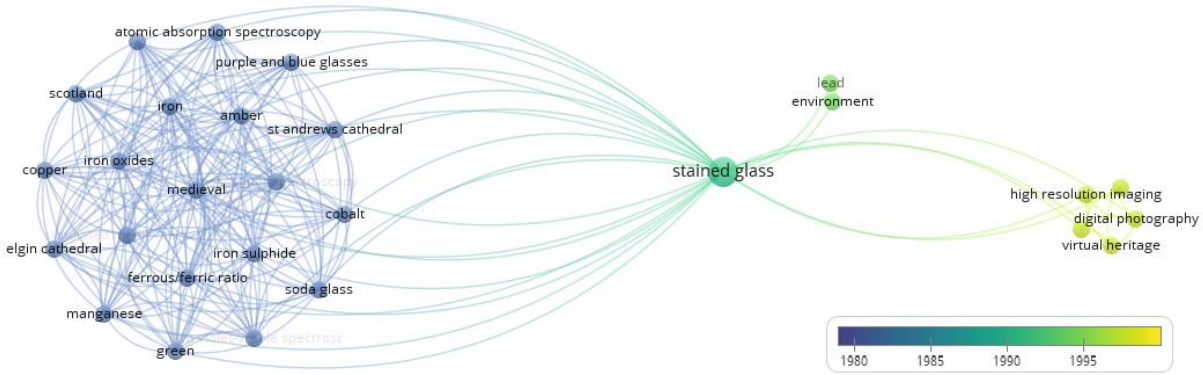

Figure 12. Cluster of keywords from 1855 to 1999

Based on the criteria mentioned earlier, the data gathered from Scopus reveals a total of 48 keywords during the specified period. These keywords were used to form two clusters: cluster 1 comprising 20 items and cluster 2 comprising 8 items, totaling 28 keywords. Publications predating 1982 did not contain keywords. Figure 12 illustrates the evolution of these two clusters from 1982 to 1999.

The visualization depicted in the figure showcases the interrelationships among various research themes, demonstrating the frequency with which certain keywords co-occur within the literature. Within the visualization, two primary clusters of keywords emerge. One cluster appears to emphasize the historical and geographical dimensions of stained glass, evident through keywords like "Scotland," "St. Andrews Cathedral," "medieval," and specific cathedral names. This cluster reflects the historical and cultural studies aspect of the field, aligning with previous analyses of publications from the same period.

Conversely, the other cluster seems to concentrate on the technical and compositional aspects of stained glass, featuring keywords such as "atomic absorption spectroscopy", "ferrous/ferric ratio", "soda glass" and various elements and compounds (e.g., "copper", "cobalt", "manganese"). These keywords suggest a focus on the scientific analysis of stained glass, including investigations into the materials and processes utilized in their fabrication.

The insights from this visualization can be tied to the distribution of publications discussed earlier. The larger cluster focusing on historical and geographical terms reflects the predominance of Arts and Humanities in the distribution of publications. The substantial representation of these keywords underscores the focus on stained glass within historical and cultural contexts, particularly within specific regions and architectural sites.

The second cluster, related to the scientific analysis of stained glass, aligns with the smaller yet significant portion of publications from the fields of Chemistry, Materials Science and Physics and Astronomy. The

presence of keywords related to specific scientific techniques and materials shows an established interest in the technical study of stained glass, which is important for understanding its composition, degradation and conservation.

The implications of these clusters are twofold. First, they suggest that the field of stained glass studies is well-established within the context of historical and cultural research, with particular attention to specific locations and periods. Second, they indicate that alongside cultural studies, there has been a consistent effort to apply scientific methods to understand and preserve stained glass.

Overall, the visualization corroborates the multidisciplinary nature of stained glass research during 1855-1999, showing a field that is both rooted in tradition and history and looking toward science and technology for its preservation and understanding.

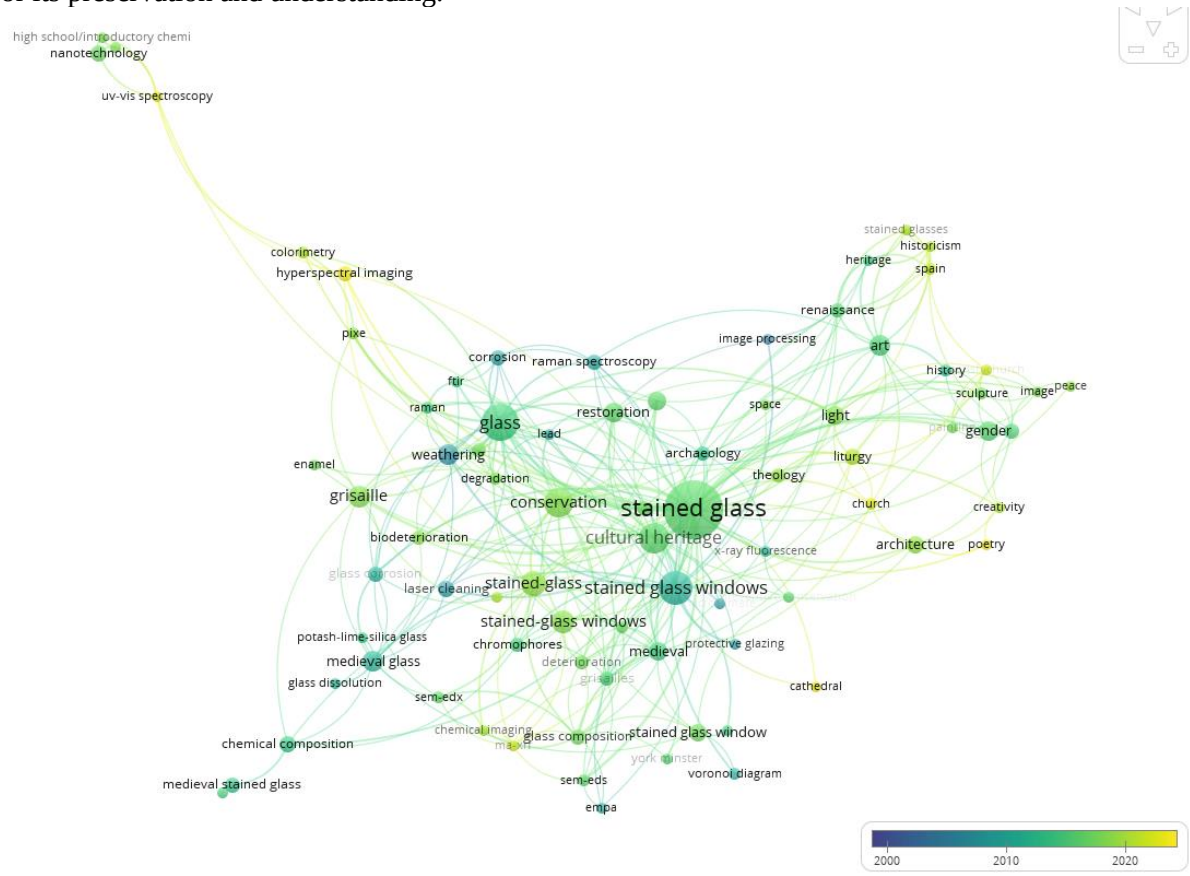

Figure 13. Cluster of keywords from 2000 to 2023

Between 2000 and 2023, a total of 1660 keywords were identified, with 83 keywords occurring at least 3 times during this period. These keywords formed a total of 11 clusters. Figure 13 illustrates the progression of these keywords over time, offering insight into the evolving landscape of stained glass research.

The provided overlay visualization presents a network of interconnected terms associated with stained glass research, indicating an expansion of the field in terms of methodologies and thematic focus. Notably, the figure highlights a significant presence of technical keywords such as "hyperspectral imaging", "Raman spectroscopy" and "laser cleaning". This suggests the integration of advanced scientific methods into the study and conservation of stained glass. Furthermore, the inclusion of terms like "UV-Vis spectroscopy" and "nanotechnology" reflects the adoption of cutting-edge technologies and materials science within the field.

Moreover, similar to the earlier period, there persists a concentration on "cultural heritage" and "conservation" now intertwined with advanced scientific methodologies. This trend possibly signifies the growing adoption of interdisciplinary approaches to comprehend and safeguard stained glass.

Terms such as "heritage", "art", "history", "church" and "architecture" indicate a sustained interest in the cultural, religious and historical significance of stained glass. However, the emergence of newer terms like "gender" and "creativity" suggests an exploration into broader socio-cultural dialogues. Additionally, keywords like "weathering", "corrosion" and "biodegradation" spotlight an emphasis on the environmental factors impacting stained glass, hinting at heightened concerns regarding its long-term preservation.

The findings suggest that contemporary research on stained glass extends beyond its historical significance, encompassing the application of diverse and sophisticated techniques for its comprehension and preservation.

The emphasis on advanced imaging and analytical methodologies aligns with the rising dissemination of publications in scientific fields such as Materials Science and Engineering from 2000 to 2023. Moreover, the incorporation of broader cultural and artistic terms reflects an expanded scope of inquiry into stained glass, underscoring its relevance in contemporary cultural discourse.

Compared to the keyword distribution from 1855 to 1999, the 2000-2023 period demonstrates an increase in scientific and technological terms. This shift indicates that the field has become more technologically driven, with a significant integration of scientific analysis into the research of stained glass. There's a notable broadening of the field to include considerations of social and cultural theories and possibly public engagement with stained glass through digital means (e.g., "virtual heritage").

Overall, the shift in keywords from the earlier period to 2000-2023 reflects the field's evolution. While the historical and cultural study of stained glass remains central, there is a marked integration of new technologies and scientific methods into research practices. This indicates a more holistic and multifaceted approach to stained glass research, which now encompasses the physical sciences, technological innovations and broader cultural studies.

4. Conclusions

This study provides a thorough analysis of stained-glass research trends, utilizing Scopus data from 1855 to 2023. By examining scholarly work over this extended period, the study identifies significant shifts in publication volume, particularly a notable surge in research interest post-2000. This rise coincides with advancements in digital technology and improved access to academic resources, which have likely broadened participation in stained glass research. The data shows that while earlier centuries exhibited modest and consistent trends, the last two decades have seen a sharp increase in both the quantity and diversity of research, driven by technological innovations and enhanced global connectivity.

Another important finding is the shift in geographical focus. Historically, stained glass research was concentrated in Europe, where the art form has deep roots. However, since 2000, there has been a diversification of contributors, with growing participation from the United States and other countries. This reflects a more globalized approach to stained glass studies, as scholars from various regions and disciplines engage with the field. The increased international involvement has enriched the research landscape, bringing fresh perspectives and methodologies, and further underscoring the interdisciplinary nature of stained glass studies.

Technological advancements have significantly impacted stained glass research, particularly in the areas of preservation and restoration. The integration of digital tools, materials science, and engineering with art history has created an interdisciplinary approach essential for studying and conserving stained glass. Techniques such as hyperspectral imaging and spectroscopy are now commonly used, allowing for more detailed analysis and preservation of these delicate artifacts. This fusion of disciplines has not only deepened the academic understanding of stained glass but also contributed practical solutions for its long-term conservation.

The study also highlights changes in the funding landscape for stained glass research. Financial support has become more diverse, fostering a collaborative and technically oriented approach to the field. The range of document types, from traditional journal articles to technical papers, reflects this shift towards a more comprehensive and applied understanding of stained glass. As scientific methodologies and public engagement play larger roles, new forms of research output have emerged, signalling broader and more diverse research practices.

These findings have both theoretical and practical implications. The rise in publications post-2000 suggests a shift in research themes, influenced by technological advancements and increased access to digital resources. This has expanded the academic discourse around stained glass, integrating traditional artistic perspectives with modern scientific methods. Interdisciplinary research, with contributions from art historians, materials scientists, and engineers, has become central to the field. Moving forward, studies will likely continue to focus on how these disciplines intersect to address the complexities of stained glass as both an artistic and historical artifact.

Practically, the study’s insights into technological advancements in conservation offer valuable lessons for improving the preservation of stained glass. The increased use of scientific methods promises more effective restoration practices. Additionally, the diversification of funding and collaboration highlights potential policy implications, suggesting that future research will benefit from continued interdisciplinary efforts and targeted funding. The growing public engagement with stained glass also underscores its broader cultural significance, with potential benefits for education and heritage tourism.

Despite the contributions of this study, there are some limitations. The reliance on Scopus as the sole database may exclude relevant publications, particularly from non-English-speaking regions or smaller

academic communities. Moreover, the focus on quantitative trends may overlook qualitative aspects, such as the depth and impact of individual research contributions. Future studies could address these limitations by incorporating more diverse databases and qualitative analysis, providing a richer understanding of the field.

Looking forward, the globalization and diversification of stained glass studies offer promising avenues for future research. Exploring different cultural, historical, and technological perspectives on stained glass could provide a more comprehensive understanding of global heritage preservation. Comparative studies of conservation practices across regions could also enhance this understanding. Interdisciplinary collaborations between art, science, and technology hold great potential for advancing both theoretical and practical applications in the field. Additionally, future research could delve deeper into the socio-cultural aspects of stained glass, including its role in public engagement, community identity, and gender dynamics. Investigating the artistic and cultural significance of modern stained glass trends could further enrich the field.

In summary, this study not only deepens our understanding of stained glass research but also provides insights relevant to other fields. By shedding light on the evolution and trends within stained glass research, it enhances our appreciation of this artistic medium and contributes to broader scholarship in art history, cultural studies, and interdisciplinary research.

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