A Bibliometric Analysis of Traffic Safety Education for Student Cyclists in the Database Scopus and Web of Science

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Abstract: This study presents bibliometric analysis of the studies regarding traffic safety education for student cyclists. A scoping research approach was employed to investigate and outline recent studies on traffic safety education, aiming to identify thematic evolution and research gaps. Eighty-seven articles published between 1990 and 2023 met the criteria. Although research were reported from different nations across four continents, the majority were from Europe and North America. The study contributes the better understanding of the traffic safety education for student cyclists. It also discusses distinctions between teach strategies, the application of technology, the duration of the intervention, and their effectiveness. Recommendations based on research gaps includes the need for studies about traffic safety education for student cyclists beyond Western societies, the application of technology as a persuasive tool, and increase collaboration between countries.

Keywords: Bibliometric, Traffic Safety, Education, Student, Cyclist

1. INTRODUCTION

The World Health Organization (2018) has established road traffic accidents as the main cause for the death of children and young adults aged up to 19 years globally. Cycling is among the popular modes of transportation that constitute road traffic accidents, influenced by many factors such as inadequate infrastructure, poor visibility, and reckless driving behavior (Beck et al., 2017; Noland et al., 2017). Since the majority of the crashes can be attributed to human errors (Sabey & Taylor, 1980), traffic safety education has been employed to improve road safety (Alonso et al., 2018; Assailly, 2017), alongside other countermeasures such as enforcement and engineering.

Traffic safety education is a learning process designed to prioritize knowledge and understanding of traffic rules and situations, improve skills through training and experience, and change attitudes towards risk awareness, personal safety, and the safety of others on the road (Dragutinovic & Twisk, 2006). With this regard, traffic safety education goes beyond merely being a subject in schools. Scholars have conducted studies on skill training, campaigns, and online platforms as means of education in the traffic safety sector (DiMaggio *et al.*, 2015; Riaz *et al.*, 2019; Zeuwts *et al.*, 2020). When implemented effectively, traffic safety education can play a significant role in increasing knowledge about road signs, situation awareness skills (Fyhri et al., 2004), changing attitudes, and correcting behaviour (Hawley et al., 2018). Studies have found that a lack of road safety knowledge is strongly associated with risky behavior, resulting in higher rates of traffic injuries among students (Dong et al., 2011; Duperrex et al., 2002). Because of its crucial role in enhancing traffic safety, traffic safety education was

proposed as a lifelong learning process in which individuals obtain knowledge and skills throughout their lifetimes (Mütze and De Dobbeleer, 2019; Thomson *et al.*, 1996).

In review studies, narrative reviews are less structured and loosely systematic than other review types since they rely on the author's own interpretation and synthesis of the literature (Lennon *et al.*, 2014). Systematic review aims to identify, evaluate and synthesize available evidence relevant to a specific research question (Valentová *et al.*, 2021). Scoping reviews can be conducted to identify and examine characteristics or factors related to a particular concept, identify and analyze gaps in the knowledge base; as a result, scoping review releases the evolution of major research themes and trends in research area (Pirri *et al.*, 2020). To visualize the significant findings in the research area, such as the number of publications, citations, authors, and journals, bibliometric analysis has been used to track the development of a research topic over time, and to identify emerging trends and areas of interest (Donthu *et al.*, 2021).

Despite the existence of studies on traffic safety education, no study that provides a scoping review and bibliometric analysis of research regarding traffic safety education for student cyclists in order to gain a comprehensive understanding about the evolution of major research themes and trends in this sector. The present study investigates publications regarding traffic safety education for student cyclists by bibliometric review to understand past and current research trends and to identify areas of future research to advance the field. To this end, Scopus and Web of Science databases were thoroughly searched and examined, and a total of 87 articles, reports, and books were discovered. The above-mentioned documents span over thirty-three years (1990-2023), and their analysis is performed using the free and open-source R tool “bibliometrix”.

2. METHODS

The study followed the PRISMA Extension for Scoping Reviews (PRISMA-ScR) (Tricco *et al.*, 2018). A two-step process was used to cover all the aspects of our research objectives as seen in Figure 1.

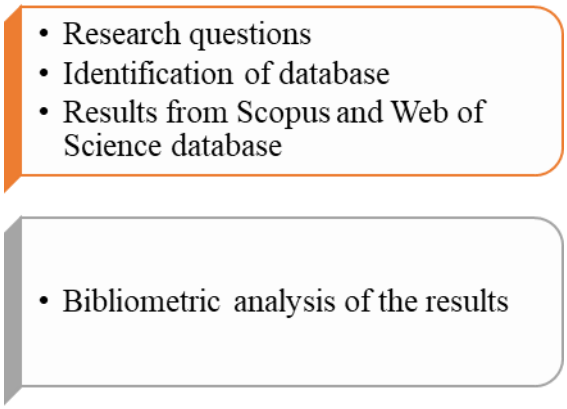

Figure 1. Study process

First step: Perform a Review adopting the Arksey and O’Malley framework. Arksey and O’Malley outlined the fundamental five steps for a scoping review: (1) identify the research question and operationalize the definitions, (2) identify relevant studies through electronic databases and reference lists, (3) establish inclusion–exclusion criteria for the selection of

studies, (4) chart the data through a narrative review, and (5) analyze, summarize, and report the results.

Second step: A bibliometric analysis from the retrieved scoping review results, to analyze the knowledge domains, and possible future research trends. The bibliometric mapping analysis gives a more comprehensive and complete overview of the extent and complexity of the topic of using two software programs: VOSviewer and the bibliometrix package in R statistical software. The bibliometric analysis was used to measure and visualize the influence of the scoping review results in the scientific community and VOSviewer explored keyword trends and the related concepts, as well as collaboration network maps.

These steps were explained in detail below.

Step 1:

Stage 1.1 development of the research questions

(1) Which journals play a significant impact for both the quantity and quality of the research work?
(2) Which nations are regarded as having the influences in the current research field?
(3) How is the collaboration among countries in the current research field?
(4) Which publications are important and provide an advantage for scientific output?
(5) Which keywords and themes have evolved over the years?

Stage 1.2 framework stage: identification of electronic databases and relevant studies

This study uses articles retrieved from the Scopus and Web of Science electronic databases. This citation property is a crucial component for the study investigation that influenced many of our decisions regarding data sources. At this stage, the eligibility criteria (Table 1), the searching strategy and keywords used to retrieve the articles were defined. All the retrieved articles were exported into Endnote, the software used to organize, select and check the articles.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria
- Articles published in English
- Selected period 1990–2023
- Research focused on traffic safety education for student using bike among other means of transportation
- Studies published in peer-review journals
- Type of studies: original articles
- Research focus on educational settings in traffic safety for student cyclist
Exclusion Criteria
- Research in which the participants, teaching strategies, measurement of the intervention's effectiveness are NOT clearly defined
- Articles without access to the full text
- Articles that do NOT include relevant information specifically designed to increase or better understand traffic safety education for student cyclists
- Double citations.

Stage 1.3 screening and selection of publications

An extensive list of primary and secondary key terms was developed iteratively, using a Boolean logic and filtering method in order to cover as many research articles as possible linked to the scope of the study. The primary search terms focused on the most common terms in the literature on traffic safety education for student cyclists, reflecting the core concept of traffic safety (e.g., traffic safety, road safety). The secondary key terms included a broader set of keywords related to factors, variables, datasets, and methodologies applied to obtain specific results on those elements in the literature. A final set of keywords was related to the means of transportation. The filtering methods included the date range, and articles written only in English.

The search query aimed to retrieve actually implemented behavior change systems with a technical component. Therefore, the following terms were used: *(educat* OR train* OR program* AND teach* OR learn* OR lecture* OR session* OR course* OR gam* OR simulat* OR class* OR online OR "practical" OR "on-road") AND ("traffic safety " OR "road safety" OR "road accident*" OR "traffic accident*" OR "road injur*" OR "traffic crash*" OR "road crash*") AND (student* OR child* OR teen* OR adolescen*)*.

The search was limited to the English articles published during January 1990 and April 2023. The process of merging the collected data is discussed below. The query search resulted in a set of 483 and 116 articles from Scopus and WoS respectively. Duplicate articles were eliminated, and the names of the authors and journals were normalized, which resulted in 87 documents. This whole process is summarized in the three stages of search strategies shown in Figure 2.

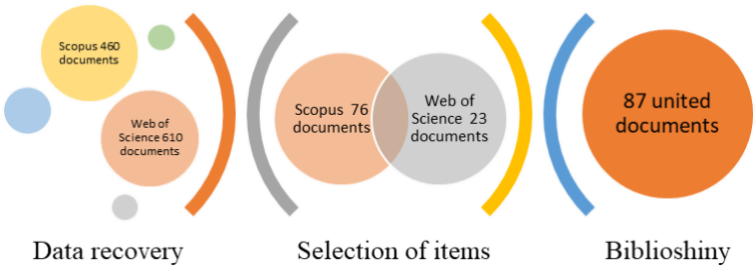

Figure 2. Searching strategy

To meet the requirements of the Analysis Software, information was retrieved from Scopus using various formats such as BibTex, CSV, and Plain Text. The process of refining articles was performed on April 16th, 2023 using a specific set of keywords and strategies outlined above, on the Scopus and Web of Science platform.

3. RESULTS

The Scopus and Web of Science databases were used for retrieving documents relevant to the domain of this study. After careful screening of abstract and data cleaning, the BibTex files from each of these databases were merged using R language, resulting in a combined database of 87 documents as an *xlsx* file. This file was then used to conduct bibliometric analysis with the *bibliometrix* package in R, along with VOSviewer software for generating some of the network visualizations.

The overarching aim of this type of study is to visualize and deduce the rather obscured associations in the retrieved bibliography, ultimately adding in summarizing the research topic and its alignment with the domain of traffic safety education for student cyclists.

As seen in Table 2, there have been 307 authors within the time span of 1990 to 2022. The retrieved count of documents is 87 out of which 73 are articles, 1 is an early access article, 1 is a proceedings paper, 1 is a book chapter, 5 are conference papers and 6 are review papers. The limited representation of book chapters, conference papers and review papers suggested that the collective research effort in the domain of traffic safety education for student cyclists is more focused on journal publications. This indicated that the common consensus in the results of studies included in the final count is not concrete enough to warrant its significant representation in book chapters. Furthermore, Table 2 also reveals 3.5 authors per document (ADP). This ADP reflects the high prevalence of collaborative research (Elango 2018), as the number of multi-authored documents exceeded that of single-authored documents, with only 6 out of 87 documents being single-authored. This is further supported by an average of 3.83 co-authors per document, indicating the paramount collaborative research efforts (Hirsch 2005).

Table 2. Main information on the document data retrieved from Biblioshiny

Main Information on the document data	
Timespan	1990:2022
Documents	87
Sources	59
DOCUMENT TYPES	
article	73
article; early access	1
article; proceedings paper	1
book chapter	1
conference paper	5
Authors	307
Authors of single-authored docs	6
AUTHORS COLLABORATION	
Co-Authors per Doc	3.83
Annual Growth Rate %	2.9
Document Average Age	15.6
Average citations per doc	17.72
Author per doc	3.5

Impact of Journals

Table 3 summarizes the impact of the top ten sources (journals), quantified by the "h-index" score and total citations. The h-index score indicated the research productivity and impact of the journal by accounting for both the quantity and quality of the research work, providing a nuanced view of the parameter (Garfield 2006). By examining the h-index score, the performance of journals were considered both citations and publications. The number of citations represented the quality of the research, while the number of publications reflected the

productivity of the journal (Hirsch 2005). Fundamentally, the h-index quantified the consistency of research output, where an h-index score of "N" signified that there were "N" papers with minimum "N" citations (Norris and Oppenheim 2010). "ACCIDENT ANALYSIS AND PREVENTION" has the highest h index score of 7, which was still modest compared to h-indices of other research domains, where scores reached double digits. This confirmed the lack of popularity of traffic safety education for student cyclists as a research area among researchers. Alternatively, a speculation can be drawn in the sense that the acceptance rate of research associated with student cyclists is lower than other such topics, even in a journal such as "ACCIDENT ANALYSIS AND PREVENTION", which is widely preferred in the field of road safety education (Abdullah 2021). "PEDIATRICS" has the highest number of citations, ensuring productivity; however, its h-index score of "5" raised questions about the quality of research in the domain of bicycle safety education published in this journal. The highest total citations is boasted by "PEDIATRICS" with 334 total citations, while "ACCIDENT ANALYSIS AND PREVENTION" has 193 total citations.

Table 3. Impact of top ten journals as retrieved from Biblioshiny

Journal	**h_index**	**Total Citations**
ACCIDENT ANALYSIS AND PREVENTION	7	193
INJURY PREVENTION	6	166
PEDIATRICS	5	334
INJURY PREVENTION : JOURNAL OF THE INTERNATIONAL SOCIETY FOR CHILD AND ADOLESCENT INJURY PREVENTION	2	49
JOURNAL OF COMMUNITY HEALTH	2	26
JOURNAL OF EPIDEMIOLOGY AND COMMUNITY HEALTH	2	24
HEALTH PROMOTION PRACTICE	2	18
TRANSPORTATION RESEARCH RECORD	2	5
FUTURE OF CHILDREN	1	117
ANNUAL REVIEW OF PUBLIC HEALTH	1	84

Authors, Journals and Related Countries

A Sankey diagram is utilized to demonstrate the connection between three variables in a Three-Field Plot (Cobo et al. 2011a). In this scenario, the Three-Field Plots employ the variables of authors, journals and authors' countries in that particular order. Figure 3 shows such a Sankey diagram generated using Biblioshiny. Only the first fifteen nodes were used in generating the figure. The dimensions of the columns represent the rank of the parameters. In the figure, Rivara has contributed the most in the research area as an author with documents routed to multiple journals. "Accident Analysis and Prevention", "Transportation Research Record", "Health Promotion Practice" and "Injury Prevention" are some of the highest contributing journals in this field of research as the output is seen to be substantial. The USA has a remarkably large contribution to the research domain as shown in the figure, followed by Canada. The column size for the USA is paramount as compared to other countries. The claim that there is regional

disparity in the research effort and scientific production is once again validated with the help of this plot apart from being explained in previous sections of this study.

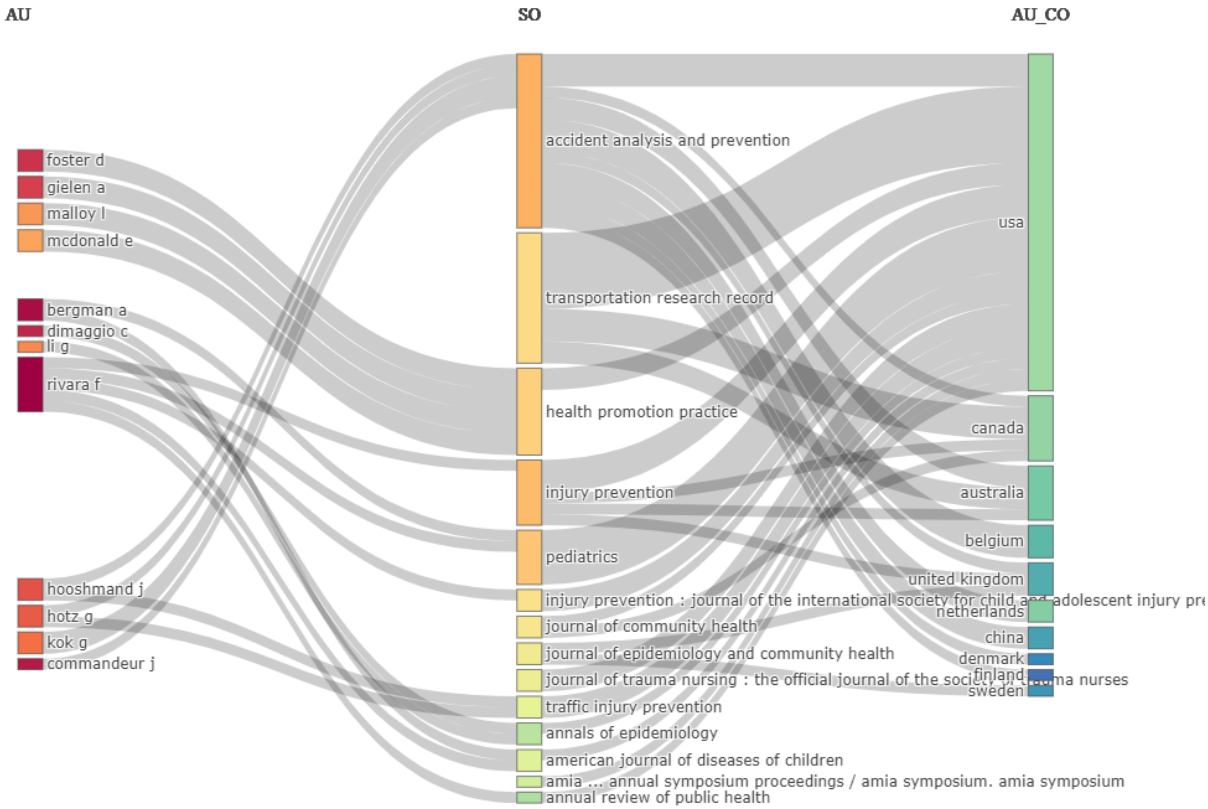

Figure 3. Three-field Sankey plot of authors, sources and authors' countries as retrieved from Biblioshiny

Regional Production and Citations

Table 4 depicts the top ten countries arranged in hierarchy of frequency of research production, and the corresponding total citations and mean document citations. The USA is seen to lead very much ahead with a frequency of 50, 762 total citations and each article from the USA has an average citation of 29.31. This suggests that the priority of research in traffic safety education is evidently high in the USA by a large extent as it is seen that country in second position, Canada, falls short in terms of frequency by 39 and 201 total citations (less than the USA by 561). The countries that follow are: the Netherlands, Australia, South Korea, Belgium, the UK and China. The same results regarding world map representation of scientific production are also displayed in Figure 3.

Table 4. Frequency, total citations and mean document citations of particular regions as retrieved from Biblioshiny

Region	Frequency	Total Citations	Mean Document Citation
USA	50	762	29.31
CANADA	11	201	28.71
NETHERLANDS	9	118	23.60
AUSTRALIA	8	62	15.50
SOUTH KOREA	6	1	0.25
BELGIUM	5	54	18.00

UK	4	56	14.00
CHINA	2	0	0.00

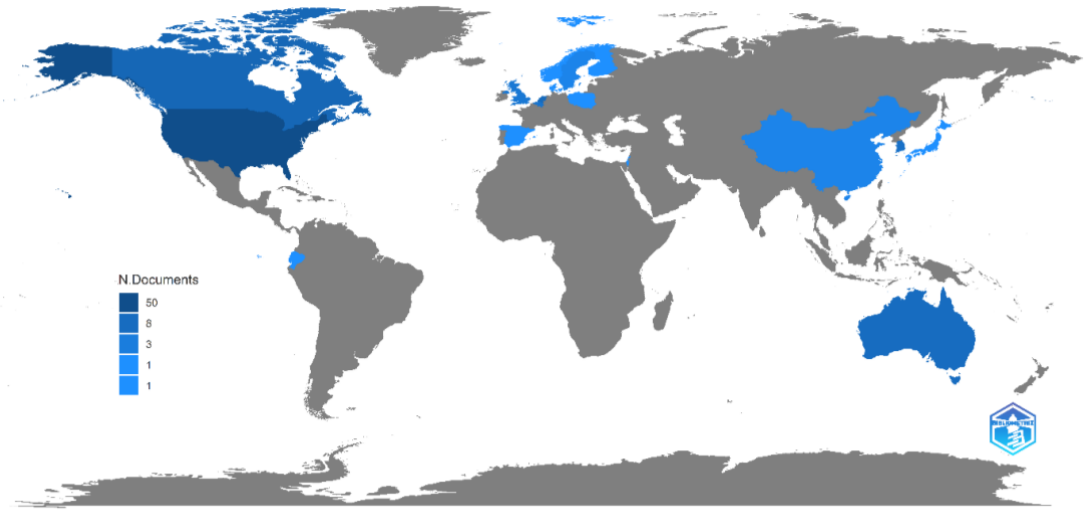

Figure 3. World map representation of scientific production as retrieved from Biblioshiny

Country Collaboration

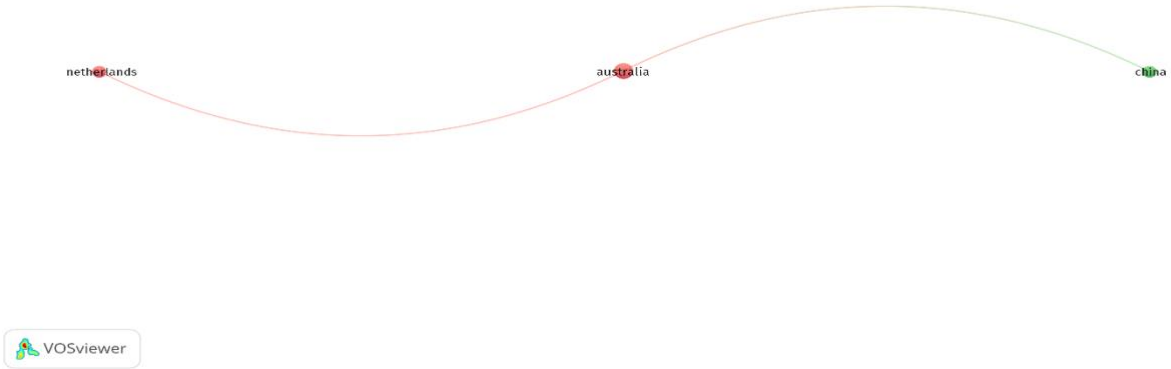

Figure 4. Country collaboration of articles

Country collaboration of articles focusing on traffic safety education for student cyclists is presented in Figure 4, with a colorized visual of the network analysis using the VOSviewer program. Circle sizes increase with the number of publications from each country. A similar coloring code is used to indicate the studies that refer to one another and the lines between the

circles demonstrate the countries studying related topics. As shown in Figure 4, country collaboration of articles happen between Netherlands and Australia, and between Australia and China.

Most Cited Documents

The top ten most documents with the highest total citations and corresponding total citations per year are as shown in Table 5. “THE SEATTLE CHILDREN'S BICYCLE HELMET CAMPAIGN CHANGES IN HELMET USE AND HEAD INJURY ADMISSIONS” has the highest total citations of 147 and 4.9 total citations per year. The same document is authored by Rivara, the most impactful author. The top ten documents thoroughly conform to the research area which focuses on road safety education for student cyclists in which training and campaign are among the most popular strategies for teaching. All documents in the table show a highly commendable level of attachment to the overarching concept of the rather obscure research domain.

Table 5. Top ten most cited documents as retrieved from Biblioshiny

Documents	Total Citations	Total Citations/Year
THE SEATTLE CHILDREN'S BICYCLE HELMET CAMPAIGN CHANGES IN HELMET USE AND HEAD INJURY ADMISSIONS	147	4.90
COMMUNITY BASED INJURY PREVENTION INTERVENTIONS	117	4.88
BICYCLE HELMET USE AMONG MARYLAND CHILDREN EFFECT OF LEGISLATION AND EDUCATION	114	3.56
PREVENTION OF BICYCLE RELATED INJURIES HELMETS EDUCATION AND LEGISLATION	84	3.23
THE SEATTLE CHILDREN'S BICYCLE HELMET CAMPAIGN	77	2.26
EFFECTS OF HAND CYCLE TRAINING ON PHYSICAL CAPACITY IN INDIVIDUALS WITH TETRAPLEGIA A CLINICAL TRIAL	62	4.13
SCHOOL BASED BICYCLE SAFETY EDUCATION AND BICYCLE INJURIES IN CHILDREN A CASE CONTROL STUDY	38	1.46
FIVE ROAD SAFETY EDUCATION PROGRAMMES FOR YOUNG ADOLESCENT PEDESTRIANS AND CYCLISTS A MULTI PROGRAMME EVALUATION IN A FIELD SETTING	37	3.70

PROMOTION OF BICYCLE HELMET USE AMONG SCHOOLCHILDREN A RANDOMIZED CLINICAL TRIAL	35	1.06
THE EFFECTIVENESS OF A BICYCLE SAFETY PROGRAM FOR IMPROVING SAFETY RELATED KNOWLEDGE AND BEHAVIOR IN YOUNG ELEMENTARY STUDENTS	35	7.00

Keywords

The word cloud of 100 words was generated using Biblioshiny as shown in Figure 5. The parameter for this visualization was set to "keyword plus" with the intention of studying any difference or notion of straying away from the research theme. All the keywords in the cluster have appreciable meaning in the research domain and are contextually conforming. The largest keywords – "children", "education", "injury", "bicycle" and others are also among the top most frequently occurring keywords.

Figure 5. Word cloud of keywords (Keywords Plus) as retrieved from Biblioshiny

Thematic Evolution

Figure 6 displays thematic evolution, which describes the changes that have occurred in a research field over a specified period. To assess the gradual changes within the field over shorter periods of time, a three-field Sankey diagram can be employed. Figure 10 explains the evolution of the research area from 1990 to 2022. The diagram consisting of two time slices, with the years 2005 and 2015 as cutting points, was generated in Biblioshiny using the author's keywords. Following parameters were entered in the generation process: minimum cluster frequency of 5, word count of 250 and weight index of 0.1. The evolution takes place in three stages of time: 1990 – 2005, 2006 – 2015 and 2016 – 2022.

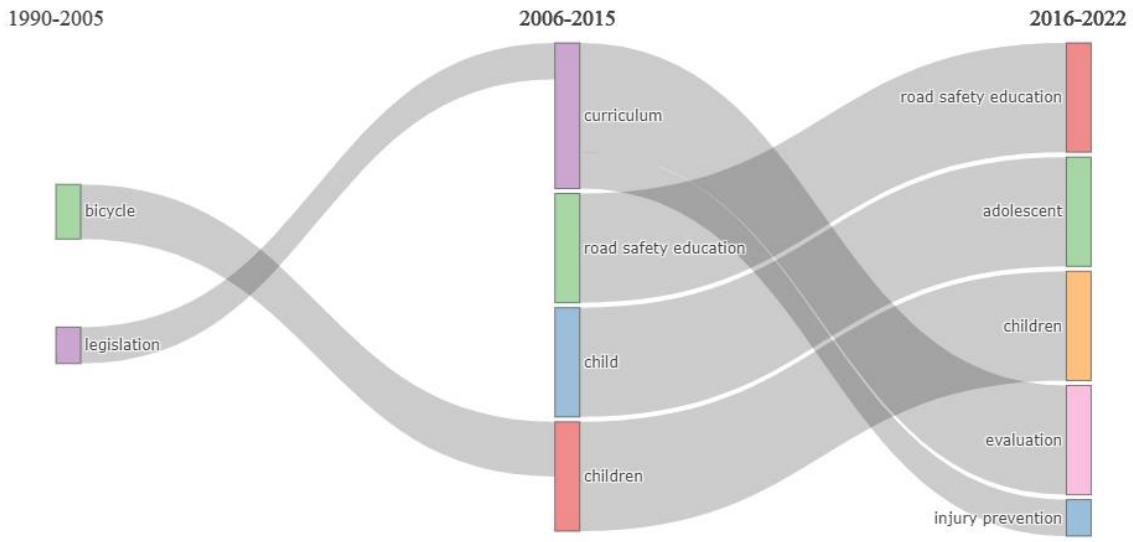

Figure 6. Sankey diagram showing thematic evolution as retrieved from Biblioshiny

4. DISCUSSIONS

This study aimed to examine publications on traffic safety education for student cyclists in the Scopus and Web of Science databases in terms of significant journals, countries, collaborations among countries, publications, keywords and themes regarding traffic safety education for cyclists over thirty-three years.

Results showed that the journal "ACCIDENT ANALYSIS AND PREVENTION" got the highest h-index score, while "PEDIATRICS" has the highest number of citations. Regarding countries that contribute to scientific research, studies were conducted in four regions: Asia, Europe, North America and Oceania. However, the majority were conducted in North America, followed by Europe. The majority of articles were published from two countries: USA and Canada. In the USA, the "Code of Federal Regulations," the "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users," and the "Highway Safety Improvement Program" provide a clear legal foundation for traffic safety education (Lee and Al-Mansour, 2020). Accordingly, road safety education in U.S. schools has been required since 1920. The Department of Transportation (DOT)'s Transportation Safety Institute (TSI) provides both theoretical and practical training for freight carriers, highway maintainers, and motorcycle riders. By distributing safety information to the public, the American Automobile Association (AAA) helps to avoid accidents. In order to raise public awareness, the NHTSA runs a variety of traffic safety awareness programs that include theme posters for bicycle safety, children's safety, drunk driving, and bicycle safety as well as TV, radio, and web ads. Even traffic safety calendars with yearly advertising themes and plans are distributed by it (NHTSA, 2016).

In Australia, there are several ways in which road safety education for student cyclists can be conducted, including as part of a curriculum-based setting, through skill training, and as part of educational campaigns (Raftery and Wundersitz, 2011). Curriculum-based programs

can be integrated into the regular school curriculum, providing students with consistent education about road safety and cycling. These programs may cover a range of topics, including traffic rules and regulations, bike maintenance, and strategies for navigating different road conditions. By incorporating road safety education into the curriculum, schools can ensure that all students receive a basic level of education about cycling safety. Skill training programs can be conducted outside of the regular school curriculum and may involve practical training exercises such as obstacle courses, group rides, or bike maintenance workshops. These programs can help students develop the skills and confidence they need to cycle safely on the road. Skill training programs can be tailored to the specific needs of different age groups, from young children who are just learning to ride to teenagers who are preparing to ride on busy city streets. Educational campaigns can be used to raise awareness of road safety issues among students and the wider community. These campaigns may involve social media campaigns, posters, or public events such as bike safety fairs. By raising awareness of the importance of road safety for cyclists, campaigns can help encourage more students to take up cycling and to do so safely. Campaigns can also help to build support for cycling infrastructure and policies that promote safe cycling.

In Europe, the Netherlands has substantial research output which can be attributed to the high level of cycling modal share observed among Dutch commuters (Schepers et al., 2017). Dutch policy catering to obligatory road safety education inclusive of practical examinations for cyclists holds strong (Weijermars and Wegman 2011). However, evaluation studies suggest inability to relate crash rates after licensing and formal education and training (Senserrick and Haworth 2005). A researcher can seek opportunity in this seemingly contradictory finding, inducing the need for more research to explain the lack of relation and perhaps look towards the interaction of other factors such as infrastructure and legal liability. Results regarding countries implied that a gap regarding the geographic area where traffic safety education for student cyclists is researched, highlighting the need for research in broader contexts. This research gap is further evidenced when considering cooperation between the countries.

In Asia, South Korea and China are among the top ten countries arranged in the hierarchy of frequency of research production, and the corresponding total citations and mean document citations. South Korea showed a higher frequency of research production compared to China. According to Lee and Al-Mansour (2020), traffic safety education in Korea is supported by the Road Traffic Act and the Traffic Safety Act. While the Road Traffic Act mandates education before and after obtaining a driver's license, the Traffic Safety Act seeks to enhance traffic safety by outlining the responsibilities of the state and local governments regarding safety policies. The School Health Act, the Child Welfare Act, and the Act on the Prevention of and Compensation for Accidents at School detail various aspects of traffic safety education in schools. Additionally, traffic safety campaigns in school zones and strict enforcement encourages public participation to enhance traffic safety in Korea.

While education is one of 5 E's to effectively enhance traffic safety in countries. There was a lack of frequency of research production in developing countries, where traffic crashes account for a significant number of fatalities and injuries. This highlighted the urgent need for research about traffic safety education in these countries.

Collaborations in research were found only among the Netherlands, Australia, and China, indicating a concentrated effort among these countries to share knowledge and resources. This collaboration suggests a mutual interest in addressing traffic safety among countries. The absence of collaboration with other nations highlights the unique relationships that these three countries have developed, potentially leading to significant advancements that could benefit broader global initiatives.

The study titled "THE SEATTLE CHILDREN'S BICYCLE HELMET CAMPAIGN

CHANGES IN HELMET USE AND HEAD INJURY ADMISSIONS" had the highest citation. This study aimed to describe the impact of a community bicycle helmet campaign on helmet use and the incidence of bicycle-related head injuries. Other highly cited studies also focused on safety programs and helmet use for child cyclists.

The most popular keywords in this research field includes "children", "education", "injury", "bicycle". The theme evolution was expanded from "bicycle" and "legislation" to include "road safety education", "curriculum", "children", "adolescent", "evaluation", and "injury prevention". The first stage shows the researchers priority in enhancing legislation to ensure safety in road safety for cyclists. Diversification and introduction of other domains in the research area is seen in the subsequent stages. In these stages, researchers realised that legislation alone cannot ensure the safety objectives. Traffic safety education and the study and reforms in the associated curriculum were identified as crucial domains. The research effort also narrowed down to children and adolescents, as active modes of transportation are more popular among these age groups.

5. CONCLUSIONS

This study offers an overview of traffic safety education for student cyclists over the past thirty-three years, revealing significant trends and gaps in the literature. North America, particularly the USA and Canada, leads in research supported by robust legal frameworks. However, there is a notable lack of focus on developing countries, where traffic-related injuries are an urgent problem. The analysis highlights limited collaboration among a few countries, suggesting a need for broader international partnerships to improve traffic safety strategies. Research themes have evolved from legislation to encompass education, curriculum reform, and practical training, emphasizing the importance of targeting children and adolescents. Future research should address these gaps and explore the interplay between infrastructure, education, and policy. By adopting a comprehensive approach, young cyclists with the necessary skills should be focused to ensure safer roadways and reduce injuries.

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