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A Systematic Review of Web-Based Learning in Enhancing Visualization Skill

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ABSTRACT

In the digital era, visualization skills are critical for academic and professional success. This systematic review examines how web-based learning enhances these skills across various disciplines. This study focuses on addressing the challenges of developing effective visualization capabilities and the role of web-based learning in providing innovative solutions. This research utilized the PRISMA methodology to identify primary data utilizing specific keywords. Through extensive searches on Scopus, Web of Science, and ProQuest, 40 relevant studies were identified. The findings are organized into three themes: (1) Learning Innovations, (2) Digital Visual Education, and (3) Creative Visual Pedagogy. Results highlight web-based learning as a pivotal strategy in applied science and technology education, emphasizing collaborative and interactive technologies in enhancing spatial visualization and contributing to advanced educational practices.

1. Introduction

In our increasingly technology world, the capacity to comprehend, interpret, and proficiently convey intricate information using visual representations has emerged as a vital aptitude across multiple academic and professional realms [1]. This skill, known as visualization proficiency, empowers individuals to utilize visuals like graphs, diagrams, charts, and multimedia presentations for information dissemination, problem-solving, and informed decision-making [2,3]. Proficiency in visualization is not just a fundamental aspect of digital literacy but also a pivotal competency in fields ranging from STEM (Science, Technology, Engineering, and Mathematics) to the humanities, where data-driven decision-making and effective communication hold significant importance [4,5]. The emergence of web-based learning has ushered in an era of transformation in education, presenting unprecedented opportunities for cultivating and enhancing visualization skills [6-8]. Web-based

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learning, encompassing various digital teaching methodologies, harnesses the internet and interactive technologies to deliver educational content and facilitate diverse learning experiences [9,10]. In this digital landscape, learners gain access to a wealth of multimedia resources, interactive simulations, virtual laboratories, and collaborative platforms that cater to a wide array of learning styles and preferences [11–13] . Consequently, incorporating web-based learning into educational environments has sparked interesting discussions regarding its effectiveness in fostering visualization abilities, which impacts how educators conceptualize and present knowledge in the digital age [14].

This systematic review intends to explore the changing web-based learning environment and how it affects the development of visualization skills. The marriage of education and technology has resulted in cutting-edge pedagogical strategies and technological advancements poised to revolutionize how humans learn, use, and share knowledge [15]. To maximize the development of visualization skills, it is crucial to review the body of research already in existence, identify trends, evaluate the success of web-based learning interventions, and provide insights into pedagogical tactics [16,17]. This systematic review is significant because it can provide educators, decision-makers, researchers, and instructional designers with information on the status of the field and the function that web-based learning plays in meeting the growing need for visualization skills [18]. This review intends to provide a nuanced knowledge of how web-based learning environments influence the acquisition and application of visualization skills through a comprehensive analysis of relevant literature. Furthermore, it aims to highlight best practices, emerging trends, and areas that need more research in web-based education and visualization skill development.

As the digital revolution continues to transform education, this systematic review provides a relevant examination of the relationship between web-based learning and the development of visualization abilities. It endeavours to shed light on the multifaceted relationship between technology-enhanced education and the empowerment of individuals to navigate, comprehend, and communicate in an increasingly visual and data-driven world [19]. In doing so, this review aspires to contribute valuable insights that will inform pedagogical practices, inspire future research endeavours, and ultimately equip learners with the visualization skills necessary for success in the digital age. To sum up, the research questions are:

i. What types of learning innovations are utilized in enhancing visualization skills through web-based learning?
ii. How does digital visual education contribute to the improvement of visualization abilities through web-based learning methods?
iii. How can web-based learning that employs creative visual pedagogy improve students' abilities to visualize concepts?

2. Literature Review

The intersection of digital technologies and education has brought about a significant transformation, allowing the smooth incorporation of online learning into conventional educational environments [20-22]. This has led to a fundamental change in teaching methods, with educators utilizing online platforms and interactive resources to involve students and support their learning actively [23]. Within this context, enhancing visualization skills and learning have become key objectives, underscoring the vital role of visual literacy in promoting critical thinking, data analysis, and effective communication [23,24]

Proficiency in visualizing information, encompassing the capacity to perceive, generate, and modify visual representations of data and concepts, is important in a society inundated with

information [25]. Within academic and professional realms, individuals frequently encounter complex datasets, scientific illustrations, geographical maps, and statistical graphs [26]. Figure 1 illustrates the fundamental data visualization process, wherein data in diverse formats can be transformed into visual depictions [26]. Proficiency in visualization empowers students and professionals to extract insights from visual data, facilitating enhanced decision-making and problem-solving capabilities. Consequently, educators and instructional designers increasingly stress the importance of equipping students with the tools and skills necessary to engage with and use visual information effectively. Online learning, commonly referred to as web-based learning or e-learning, appears to hold significant potential for improving the ability to visualize information [27]. The digital environment provides a dynamic platform for integrating multimedia elements, interactive simulations, and collaborative features, enabling learners to interact meaningfully with visual content [28].

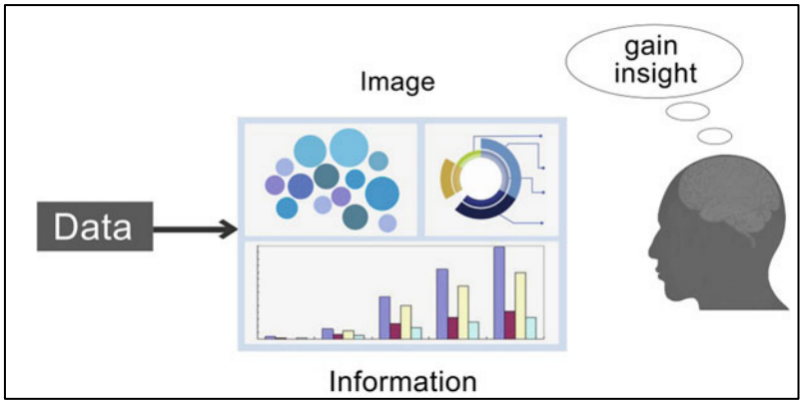

Fig. 1. Yaqin Fu demonstrates the technique of visualizing data [26]

One of the key benefits of web-based learning lies in its capacity to provide dynamic and immersive educational settings [29]. These online environments often incorporate multimedia elements like videos, simulations, and interactive visuals, enabling learners to engage with visual materials actively. Through these interactive learning experiences, students can manipulate data, visually explore complex ideas, and gain a deeper understanding of the subject matter [30]. By allowing learners to interact directly with visual representations, such settings adapt to various learning styles and enhance the development of visualization skills. Multimodal resources that convey information in several formats are frequently available in web-based learning environments. Text, photos, animations, videos, and interactive features are examples of resources [31]. Learners can get a more comprehensive knowledge of complex subjects by combining visual and textual information [32]. Furthermore, incorporating multimedia allows learners to interact with visual representations and developmental models, which helps to improve visualization skills [33].

Adaptive web-based learning systems are intended to adjust educational content to individual learners' requirements, preferences, and progress. Personalized learning routes frequently include visualization-rich content tailored to different learning styles [34]. These methods provide a customized approach to developing visualization skills by responding to learners' strengths and shortcomings. For example, a learner who excels at reading data visualizations may be given more advanced problems, while another may receive further support and instruction. Web-based learning environments also facilitate collaborative learning experiences, where students can collaborate on visualization projects, share insights, and provide feedback to peers [35]. Collaborative settings foster peer learning and enhance visualization skills through collective problem-solving [36]. Learners not

only engage in creating and interpreting visual content but also benefit from diverse perspectives and approaches to visualization.

3. Material and Methods

3.1 Identification

The systematic review comprised three key phases in selecting numerous pertinent papers for this study. Initially, keywords and associated terms were discovered by consulting thesauruses, dictionaries, encyclopaedias, and previous research. Following compiling all pertinent terms, search queries for the Scopus, Web of Science (WoS), and ProQuest databases were constructed (refer to Table 1). During the initial stage of the systematic review, 226 articles were effectively obtained from the three databases.

Table 1
The search strings

Database	Search string
Scopus	TITLE-ABS-KEY ((("web-based" OR "web based" AND learning) OR "e-learning" OR "elearning" OR "Electronic learning" OR "online learning" OR "computer-based learning" OR "computer based learning" OR "distance learning" OR "visual learning" OR "digital learning" OR "internet-based learning" OR "internet based learning" OR "virtual learning" OR "distance education" OR "cyberlearning" OR "remote learning" OR ("web-based" OR "web based" AND education)) AND ("visualization skill" OR "visualization skill" OR "Visual literacy" OR "Graphic literacy")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final")) Access date: 9th October 2023
WoS	(("web-based" OR "web based" AND learning) OR "e-learning" OR "elearning" OR "Electronic learning" OR "online learning" OR "computer-based learning" OR "computer based learning" OR "distance learning" OR "visual learning" OR "digital learning" OR "internet-based learning" OR "internet based learning" OR "virtual learning" OR "distance education" OR "cyberlearning" OR "remote learning" OR ("web-based" OR "web based" AND education)) AND ("visualization skill" OR "visualization skill" OR "Visual literacy" OR "Graphic literacy") (Topic) and Article (Document Types) and English (Languages) Access date: 9th October 2023
ProQuest	noft((("web-based" OR "web based" AND learning) OR "e-learning" OR "elearning" OR "Electronic learning" OR "online learning" OR "computer-based learning" OR "computer based learning" OR "distance learning" OR "visual learning" OR "digital learning" OR "internet-based learning" OR "internet based learning" OR "virtual learning" OR "distance education" OR "cyberlearning" OR "remote learning" OR ("web-based" OR "web based" AND education)) AND ("visualization skill" OR "visualization skill" OR "Visual literacy" OR "Graphic literacy")) Applied filters: Article; English Access date: 9th October 2023

3.2 Screening

In the initial assessment, it is crucial not to factor in redundant items. According to established criteria outlined by scholars, 128 articles were eliminated at the outset, including 17 duplicate articles. In the following stage, 81 articles underwent scrutiny, primarily focusing on research articles, as they constitute the primary wellspring of pertinent data. It should be emphasized that this investigation excluded materials such as conferences, books, and reviews. Furthermore, the

examination was confined to studies that had been published in the English language. Table 2 shows the summary of the selection criterion for advanced searching.

Table 2
The selection criterion is searching

Criteria	Inclusion	Exclusion
Language	English	Non-English
Literature type	Article	Conference, Book, Review
Publication Stage	Final	In Press

3.3 Eligibility

At the third stage of eligibility assessment, 81 articles were initially identified. During this phase, a thorough evaluation of the titles and relevant information of these articles was carried out to confirm their alignment with the present study's inclusion criteria and research goals. As a result, 41 reports were excluded from consideration because they were not relevant to the field, had titles of little significance, contained abstracts that did not match the study's objectives, or were inaccessible articles. Ultimately, 40 publications were chosen for subsequent examination and analysis.

3.4 Data Abstraction and Analysis

In this study, an all-encompassing analysis method was employed to thoroughly assess various research approaches, encompassing quantitative, qualitative, and mixed methodologies, with the main objective being identifying pertinent subjects and subtopics. The initial data collection phase laid the groundwork for the study's focus. Figure 2 illustrates the meticulous review of 40 articles to pinpoint relevant claims and information about the subjects examined. Subsequently, the assessment encompassed recent and noteworthy studies concerning web-based learning and visualization skills, where both research findings and employed methodologies were scrutinized. Following this, collaborative efforts were undertaken by the authors and their co-authors to delineate overarching themes grounded in the study's data. Throughout the data analysis, all analyses, viewpoints, inquiries, and pertinent concepts were systematically logged for future reference. To ensure uniformity in theme development, the authors compared their results and resolved disparities through constructive deliberations. Notably, these discussions involved a thorough exploration of differing perspectives. Ultimately, the generated themes were adjusted to maintain consistency and alignment. To validate the relevance and lucidity of these themes, three specialists conducted an expert review, comprising an expert in visualization teaching and learning and another in educational technology. This expert review phase was intended to corroborate each subtheme's clarity, significance, and applicability by leveraging domain-specific expertise.

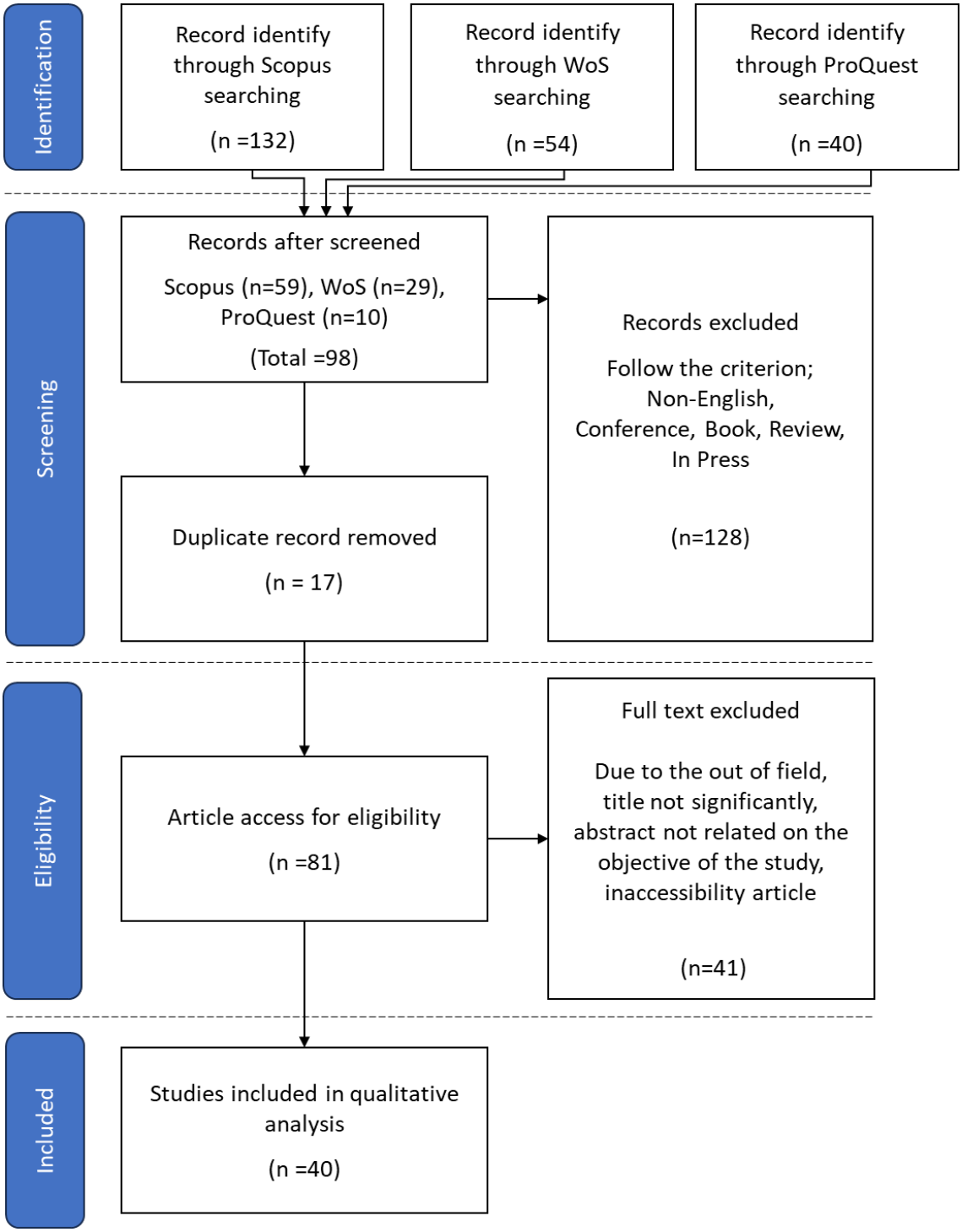

Fig. 2. Flow diagram of the proposed search study [37]

3.5 Coding

The process of codifying the findings of each article involves a systematic approach that begins with the identification of relevant research articles using keyword searches across databases like Scopus, Web of Science, and ProQuest. After an initial selection, redundant or irrelevant studies are eliminated. The selected articles are then assessed for their relevance based on titles and abstracts, leading to a refined pool of studies. For the analysis, a comprehensive review of the methodologies and findings is undertaken, with themes and sub-themes identified through collaborative efforts. The

thematic categorization is based on the key topics addressed by the studies, such as learning innovations, digital visual education and creative visual pedagogy. The findings from these studies are then abstracted and synthesized, with input from domain experts to ensure clarity and relevance. This codification allows for the distillation of a wide range of research into coherent themes that underline the contributions of web-based learning innovations to the enhancement of visualization skills in educational settings.

4. Result and Finding

Web-based learning, also known as online education or e-learning, utilizes the internet and digital technologies to deliver educational content and support learning. It employs web platforms, software, and digital resources to offer students educational materials, interactive activities, assessments, and communication tools [38,39]. In this review, it narrowed the selection to 40 articles from an initial pool of 226 through the search process. Table 3 shows the research article's findings based on the proposed search criterion. Based on the result and finding,

Table 3
The research article's findings are based on the proposed search criterion

Authors, Year	Title	Source Title	Scopus	WoS	ProQuest	Theme
Bait-Suwailam *et al.,* [40]	An Active Learning Computer-Based Teaching Tool for Enhancing Students' Learning and Visualization Skills in Electromagnetics	International Journal of Electronics and Telecommunications	/			Learning Innovation
Sanandaji *et al.,* [41]	Developing and Validating a Computer-Based Training Tool for Inferring 2D Cross-Sections of Complex 3D Structures	Human Factors	/			Learning Innovation
Bebar *et al.,* [42]	An augmented reality application for depicting space using the principles of linear perspective	Electrotechnical Review	/			Learning Innovation
Domínguez Romero & Bobkina [23]	Exploring critical and visual literacy needs in digital learning environments: The use of memes in the EFL/ESL university classroom	Thinking Skills and Creativity	/	/		Digital Visual Education
Topouzova [43]	Truth and subjectivity in narrative inquiry: augmented reality & digital storytelling in the university classroom	Journal of Visual Literacy	/			Digital Visual Education
Noble [44]	'Getting Hands on with Other Creative Minds': Establishing a Community of Practice around Primary Art and Design at the Art Museum	International Journal of Art and Design Education	/			Creative Visual Pedagogy

Sime & Themelis [45]	Educators' perspectives on transmedia identity management: Redefining tele-teacher presence	Distance Education	/			Digital Visual Education
de Bruijn [46]	The Collage Workshop: Exploring the Image as Argumentative Tool	International Journal of Art and Design Education	/	/		Creative Visual Pedagogy
Guinibert [47]	Learn from your environment: A visual literacy learning model	Australasian Journal of Educational Technology	/	/	/	Digital Visual Education
Brooks *et al.,* [48]	Building visual literacy skills on campus: A toolkit for multidisciplinary teaching from university art collections	Art Documentation	/			Learning Innovation
Fragou & Papadopoulou [49]	Exploring infographic design in higher education context: towards a modular evaluation framework	Journal of Visual Literacy	/			Creative Visual Pedagogy
Martínez-Cardama & Caridad-Sebastián [50]	Social media and new visual literacies: Proposal based on an innovative teaching project	Education for Information	/			Digital Visual Education
Loerts & Belcher [51]	Developing visual literacy competencies while learning course content through visual journaling: teacher candidate perspectives	Journal of Visual Literacy	/			Creative Visual Pedagogy
McLeod [52]	Rephotography for photographers: discussing methodological compromises by post-graduate online learners of photography	Journal of Visual Literacy	/			Creative Visual Pedagogy
Winfield *et al.,* [53]	Using important to Support a Student-Centred Activity on Alkane Conformations	Journal of Chemical Education	/	/		Learning Innovation
Gadelshina *et al.,* [54]	Understanding corruption through freehand drawings: a case study of undergraduate business students' visual learning in the classroom	Journal of Visual Literacy	/			Learning Innovation
Schönau & Kárpáti [55]	Renaming the framework: Common European framework of reference for visual competency	International Journal of Education Through Art	/	/		Digital Visual Education
Kędra [56]	What does it mean to be visually literate? Examination of visual literacy definitions in a context of higher education	Journal of Visual Literacy	/			Digital Visual Education

Goodacre [57]	Digital Learning Resources for Prosthodontic Education: The Perspectives of a Long-Term Dental Educator Regarding 4 Key Factors	Journal of Prosthodontics	/		Learning Innovation
Dabić *et al.,* [58]	Photography as visual learning tool in entrepreneurial education	International Journal of Entrepreneurship and Small Business	/		Creative Visual Pedagogy
Stoerger [59]	Writing without words: Designing for a visual learning experience	Education for Information	/	/	Digital Visual Education
Arneson & Offerdahl [60]	Visual literacy in bloom: Using bloom's taxonomy to support visual learning skills	CBE Life Sciences Education	/		Digital Visual Education
Stenliden *et al.,* [61]	Innovative didactic designs: visual analytics and visual literacy in school	Journal of Visual Literacy	/		Digital Visual Education
Ecoma [62]	The tools, approaches and applications of visual literacy in the Visual Arts Department of Cross River University of Technology, Calabar, Nigeria	Journal of Visual Literacy	/		Creative Visual Pedagogy
Avsec [63]	Investigating mechanical engineering students' design ability using learning styles	World Transactions on Engineering and Technology Education	/		Learning Innovation
Méxas *et al.,* [64]	Stereo orthogonal axonometric perspective for the teaching of Descriptive Geometry	Interactive Technology and Smart Education	/		Learning Innovation
Jiménez-Montano & Ortiz-Rivera [65]	Development of visual skills: Digital photography as a tool for research and teaching in architectural education	Communications in Computer and Information Science	/		Learning Innovation
Papadopoulou [66]	Art and technology: Visual literacy as an effective way of manipulating the environment	Mediterranean Journal of Social Sciences	/		Creative Visual Pedagogy
McLeod [67]	In the wake of SNS Challenger: Rephotographing collectively online with informal learners	Art, Design and Communication in Higher Education	/		Creative Visual Pedagogy
Britsch [68]	Image as language: Teacher-created photographs and visual literacy for English language learning	Australian Journal of Early Childhood	/		Creative Visual Pedagogy
Michael [69]	Virtual classroom: Reflections of online learning	Campus-Wide Information Systems	/		Creative Visual Pedagogy

Egwwurube [70]	Using visual documents in distance language learning: Questions raised by an e-learning Business English course	Recherche et Pratiques Pedagogiques en Langues de Specialite - Cahiers de l'APLIUT	/		Digital Visual Education
Avgerinou & Pettersson [71]	Toward a Cohesive Theory of Visual Literacy	Journal of Visual Literacy	/		Digital Visual Education
Özsevgeç *et al.,* [72]	Determination of visual literacy of preservice teachers	Journal of Turkish Science Education	/		Digital Visual Education
Rourke & O'Connor [73]	Look before you leap: Testing some assumptions on visual literacy and predominant learning modalities of undergraduate design students in Australia and New Zealand	International Journal of Learning	/		Digital Visual Education
Abrahmov & Ronen [74]	Double blending: Online theory with on-campus practice in photography instruction	Innovations in Education and Teaching International	/	/	Learning Innovation
H.-C. Wang *et al.,* [75]	The comparative efficacy of 2D- versus 3D-based media design for influencing spatial visualization skills	Computers in Human Behaviour	/		Digital Visual Education
Marwa *et al.,* [76]	Improving visualization skills in engineering education	IEEE Computer Graphics and Applications	/		Creative Visual Pedagogy
Crown [77]	Improving visualization skills of engineering graphics students using simple JavaScript web-based games	Journal of Engineering Education	/		Creative Visual Pedagogy
Trumbo [78]	Visual literacy and science communication	Science Communication	/	/	Creative Visual Pedagogy

4.1 Trend of Research

By the literature quantity analysis, the research trend of publications from 1999 to 2023 shown in Figure 3. The years 2019 and 2020 stand out with the highest count at six (6) publications each. The year 2012 also had increased activity with four publications. However, there's a noticeable decline post-2020, with three (3) publication in 2021, only one (1) publication in 2022 and a slight increase to two (2) in 2023. This fluctuation indicates varying levels of publishing activity over the years.

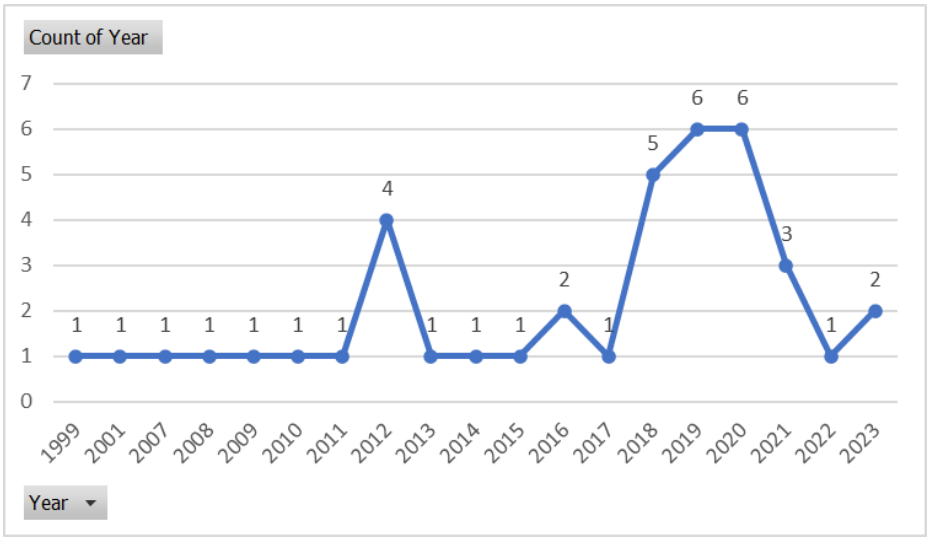

Fig. 3. Annual totals of publications

The core principle of conducting keyword research is ensuring that the keywords employed by the author effectively convey the essence of the content [79,80]. When two keywords are found together within a sentence in the article, it indicates a co-occurrence, signifying a connection between the two concepts. The findings emphasized the high frequency of keywords such as e-learning, visualization, educational technology, engineering education, visual learning, and education, highlighting a strong connection between e-learning and visualization. Figure 4 displays a map visualization of authors' keywords using VOSviewer software, highlighting the relationships between keywords through colour, circle size, font, and line thickness. Keywords with similar meanings are often grouped in the same colour. To be included, a keyword must appear at least three times.

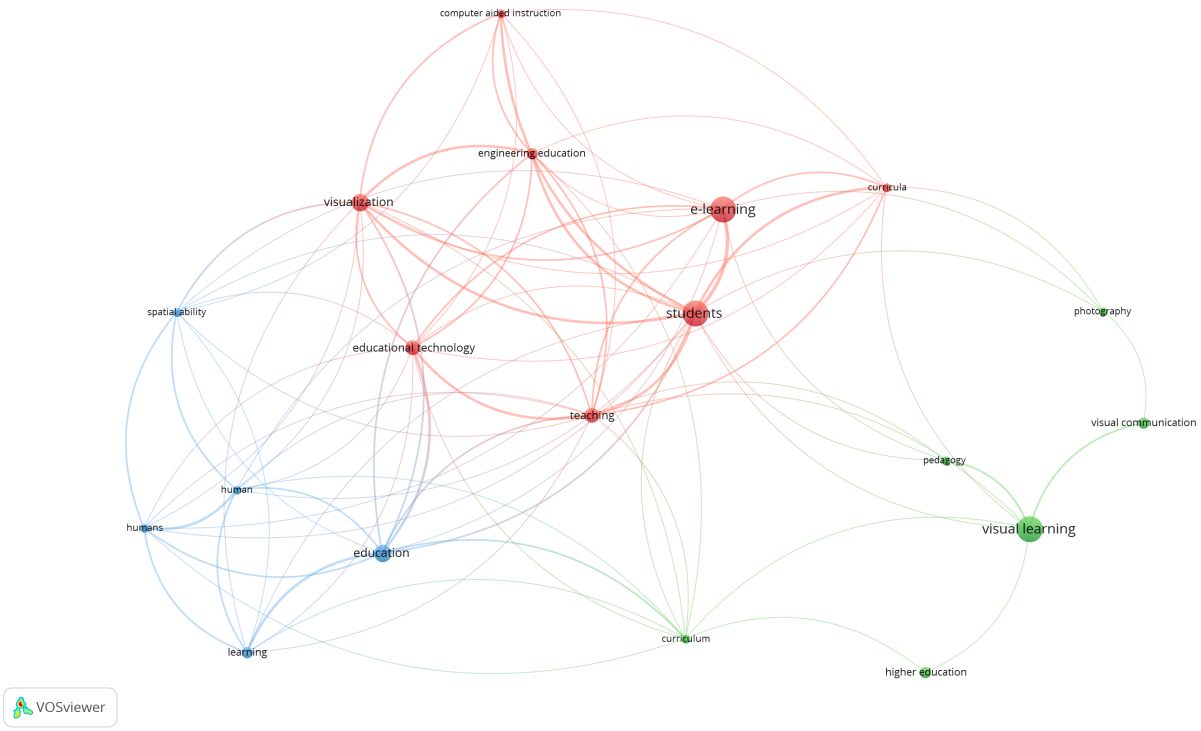

Fig. 4. Network diagram of the author keyword

4.2 Learning Innovations

Learning innovations encompass new methods and technologies in education [81], emphasizing the transformative power of technology through elements like interactive simulation, spatial training, augmented learning, and visual pedagogy. These components, each representing a distinct facet of educational technological innovation, collectively highlight the increasing relevance of digital tools and visual literacy in enriching educational experiences and outcomes. The comprehensive outcomes and insights from these innovations, as detailed in Table 4.

Table 4
Summary of learning innovation theme

Ref.	Methodology	Findings	Learning Innovation			
			Interactive Simulation	Spatial Training	Augmented Learning	Visual Pedagogy
[40]	Developed an interactive MATLAB® toolbox for teaching electromagnetic concepts and assessed student feedback.	80% of students found the interactive tool helpful for mastering electromagnetic concepts.	/			
[41]	Created a computer-based training tool for 2D cross-section understanding. Evaluated with 60 participants using pre- and post-tests.	Improved 2D cross-section skills, mental rotation, and viewpoint visualization.	/			
[42]	Designed an innovative augmented reality mobile app for teaching linear perspective. Tested its effectiveness.	Augmented reality app helps students understand and represent space in linear perspective drawing classes.			/	
[48]	Developed web-based lesson plans using ACRL's Visual Literacy Standards.	Recommendations for creating multidisciplinary art collections-based teaching programs.				/
[53]	Developed iSpartan-enabled activity for organic chemistry, no lectures, group discussions.	Improved student ability to interpret Newman Projections, survey indicates value in activity for comprehension.	/			
[54]	Case study with 1st-year undergraduate students using visual learning to develop critical thinking about corruption.	Visual learning helps 'digital natives' think critically about complex issues like corruption.				/
[57]	This study uses 3D education programs in dentistry classes, focusing on spatial ability, interactivity, critical thinking, and clinical correlations.	Regular in-class use and testing of students on program content enhance 3D visualization skills and spatial ability.		/		

[63]	An empirical study compared 357 engineering students from two universities. It used factor analysis to link visual learning preference and thinking style to design ability.	Visual learning preference, sequential thinking, and structure need significantly predict design ability. Gender had no significant difference in spatial visualization skills for engineering design.		/	
[64]	Developed stereo visualization software for teaching Descriptive Geometry using GeoGebra.	Students found the new method superior for spatial visualization compared to traditional techniques.	/		
[65]	Studied digital photography to understand learning processes in architectural design.	Enhanced education strategies for developing visual skills in design, fostering collaboration between faculty and librarians.			/
[74]	Blended learning with online components for enhanced teaching outcomes.	Successful integration of visual literacy into practical courses, applicable in diverse subject areas.			/

Interactive simulation covered in four (36%) articles, focuses on the development of interactive digital tools for enhancing learning and visualization skills in various academic fields, such as electromagnetics and geometry. The articles illustrate the effectiveness of these tools in improving students' understanding and mastery of complex concepts through interactive simulations. Spatial training encompassing two (18%) articles, this sub-theme highlights the significance of spatial training in educational contexts. It emphasizes the role of learning styles in enhancing the design abilities of students, particularly in mechanical engineering and dental education, showcasing how spatial training can be effectively integrated into curriculum.

Augmented learning represented by one (9%) article; this sub-theme explores the application of augmented reality in education. It demonstrates how augmented reality can be used to enhance students' spatial understanding and visualization skills, particularly in the context of linear perspective. Visual pedagogy highlighted in four (36%) articles and focuses on the integration of visual literacy and digital tools into pedagogical practices. The articles discuss various approaches to building visual literacy skills, such as using digital photography in architectural education and innovative teaching tools like augmented reality apps.

4.3 Digital Visual Education

Digital Visual Education involves employing digital graphics and interactive media in teaching, aiming to improve learning through engaging visual tools and technology [82]. The theme underscores the complex interplay between visual and digital literacies within educational frameworks. Underpinning this theme are two subthemes: 'Visual Literacy and Pedagogy' and 'Digital and Media Literacy'. Collectively, these areas underscore the essential role that visual and digital proficiencies play in modern pedagogy. A comprehensive summary of these themes is presented in Table 5.

Table 5
Summary of digital visual education theme

Ref	Methodology	Findings	Digital Visual Education	
			Visual Literacy and Pedagogy	Digital and Media Literacy
[23]	Conducted classroom study with 52 final-year English Studies students using meme-based activity and rubric.	Emphasize critical thinking and visual literacy skills in EFL/ESL classrooms; students lack preparation in interpreting cultural meanings and intentions of multimodal texts.	/	
[43]	Integrating interdisciplinary knowledge, exploring written vs. visual discourse, and merging academic and documentary approaches.	Visual literacy pedagogy combines academic and film elements, facilitating interdisciplinary collaboration and digital media production	/	
[45]	Interviewed 18 educators on identity and visual media in distance education.	Transmedia identity management is crucial for online educators, enhancing trust in online learning communities.	/	
[47]	Developed a rhizomatic m-learning model for visual literacy through heuristic inquiry and user-centred design.	Informal, environment-based visual learning facilitated by mobile learning can complement formal education for visual literacy.	/	
[50]	Evaluated the use of Twitter for collaborative reading in a theoretical course.	Twitter engagement increased through visual elements (GIFs, memes), promoting critical thinking and creativity in learning.		/
[55]	ENViL renamed the Common European Framework of Reference for Visual Literacy to CEFR-VC in 2018.	Renaming as CEFR-VC emphasized competency and clarified the concept of visual learning.	/	
[56]	Examined 11 visual literacy definitions, proposed VL skills, and recommended an assessment method for higher education.	Visual literacy is vital, often neglected in higher education; proposed skills-based assessment method to address this gap.	/	
[59]	Redesigned final paper using digital infographics in an information technology course.	Improved understanding, personal significance, and a desire to share among students.	/	
[60]	Developed Visualization Blooming Tool (VBT) for enhancing scientific visual literacy in undergraduate biology.	VBT aids curriculum redesign efforts to improve scientific visual literacy in undergraduate biochemistry.	/	
[61]	Collaborative teacher-researcher team investigates innovative lesson plans combining visual analytics (VA) and knowledge visualization (KV) to enhance student visual literacy and knowledge construction.	Teachers prioritize not just teaching VA but also enabling students to demonstrate growing knowledge, a more challenging task.		/
[70]	Compared video viewing experiences in on-campus and off-campus Master of Management classes.	On-campus students decoded visual cues better; off-campus students needed teacher mentoring for comprehension. Raises questions about learner autonomy in self-directed learning.		/

[71]	Reviewed and synthesized VL studies for a cohesive theory.	Proposed VL theory includes Visual Perception, ViL, Visual Learning, Visual Thinking, and Visual Communication, with key insights about ViL.	/	
[72]	Developed a 25-item scale for visual literacy among 216 senior preservice teachers using a survey study with principal component analysis.	Most preservice teachers showed high visual learning proficiency, preferring newspapers and computers for communication and using computers for homework and research.	/	
[73]	Employed questionnaire, F-sort, and Q-sort methods on design students to assess visual literacy and learning modes.	Visual literacy and learning modes vary among design students, suggesting a need for diverse teaching strategies.	/	
[75]	Compared 2D and 3D media for spatial visualization in 23 science majors using web-based learning.	No significant difference but medium effect favouring 3D, suggesting potential for further research.		/

Visual Literacy and Pedagogy, with eleven (73%) related articles, delves into the multifaceted nature of visual literacy, addressing its necessity in pedagogical practices and its role in enhancing critical thinking and communication skills. This sub-theme explores the didactic value of visual elements and their effectiveness in augmenting learning across disciplines. Digital and Media Literacy, documented in four (27%) articles, examines the integration of digital tools and media in the learning process. This sub-theme underscores the significance of media design and analytics in fostering spatial visualization skills and supporting autonomous learning environments. The fusion of these literacies points towards a pedagogical shift where digital fluency is as crucial as traditional literacies, proposing a redefined framework for educational practices that align with contemporary technological advancements.

4.4 Creative Visual Pedagogy

Within the thematic scope of creative visual pedagogy, the findings synthesize insights from fourteen academic articles, categorically divided into 'Artistic Methods' and 'Visual Learning Tools.' Four (29%) articles dedicated to Artistic Methods illuminate the significance of integrating art into educational practice, demonstrating the enhancement of critical thinking, creativity, and engagement in a multidisciplinary context. These studies argue for the utility of artistic approaches, like museum-based learning and collage workshops, as catalytic in fostering visual argumentation and deepening learners' interpretative skills.

Meanwhile, Visual Learning Tools are extensively explored in ten (71%) articles, revealing a comprehensive impact on students' visual literacy and learning abilities across disciplines. This sub-theme encompasses studies showcasing the effectiveness of employing visual aids, such as infographics and photography, in enriching language development and conceptual understanding. Additionally, it highlights the transformative role of technology-mediated visual tools in creating engaging learning environments, as evidenced by the successful integration of web-based games in engineering education and the exploration of virtual classrooms. Collectively, these findings advance the discourse on visual literacy, advocating for an educational paradigm where visual and artistic methods are seamlessly integrated with technological tools to equip learners with the necessary skills for a visually-oriented and technologically-driven future.

Table 6
Summary of creative visual pedagogy theme

Ref.	Methodology	Findings	Creative Visual Pedagogy	
			Artistic Methods	Visual Learning Tools
[44]	Practitioner-led action research, art museum training, teacher feedback, student involvement.	Art museum CPD improved teacher knowledge, creativity, and student engagement in art education.	/	
[46]	Utilized collage to foster critical visual thinking skills in architectural education.	Collage facilitates visual argumentation and enhances understanding in an image-rich context.	/	
[49]	Assessing 24 student-produced infographics using a modular evaluation framework in a Higher Education program.	Revealed insights into students' visual literacy skills for content generation and data visualization.		/
[51]	Qualitative case study using interviews, dialogue transcriptions, visual journals, and MCC analysis.	Academic visual journals in higher education promote diverse communication modes, creativity, reflection, and deepen learning through transmediation.	/	
[52]	Surveyed online MA Photography students on rephotography's role in visual education.	Rephotography enhances visual literacy for photography students by examining past images with depth and accuracy.		/
[58]	Analysed impact of visual learning tool on students in entrepreneurship courses.	Visual tools enhance students' visual literacy, aiding in conceptual development and preparing graduates for global challenges.		/
[62]	Examined visual arts training's impact on students' visual literacy skills through art production and findings from students' works.	Visual arts education enhances students' visual literacy, enabling them to encode and decode visual meanings effectively.	/	
[66]	Analysing the impact of technology on human perception and cognition.	Technology blurs the line between perception and reality, affecting how we process and use visual information.		/
[67]	Examined contributions to a social network project on rephotography for visual literacy and digital skills	Rephotography via a dedicated social network can enhance visual literacy and digital skills in informal learners.		/
[68]	The study offers three teacher guidelines for integrating images into language development and content learning.	Utilizing images with language objectives enhances content and visual learning across subjects.		/
[69]	Qualitative study on Elluminate Live! experiences over 12 months.	Identified themes include flexibility, cost reduction, technical challenges, resistance, online expansion, and visual literacy skills. Staff training and support are needed for successful virtual classrooms.		/
[76]	Employed dual approach with web-based graphics and sketch-based modelling for spatial ability enhancement in engineering students.	Improved students' spatial skills through combined use of digital graphics and sketching.		/
[77]	Created web-based games using JavaScript for teaching engineering graphics visualization skills.	Games improved student performance on exams and received positive feedback, enhancing the effectiveness of the instructional CD.		/

[78]	Study explores visual literacy's role in science communication using a holistic framework.	Visual literacy, encompassing thinking, learning, and communication, aids science communication effectively.	/

5. Discussion

5.1 Type of Learning Innovations

The finding represents a multifaceted approach to using web-based learning innovations to enhance visualization skills. Each theme contributes uniquely to the educational experience, catering to different learning styles and subject matter requirements. The integration of these innovative methods into curricula can lead to a deeper understanding of complex concepts, improved spatial reasoning, and a more engaging learning environment for students.

Interactive simulations are a powerful tool in web-based learning environments, offering a dynamic way for students to engage with material that may be difficult to grasp through traditional methods. For instance, an Active Learning Computer-Based Teaching Tool can significantly enhance students' learning and visualization skills in subjects like electromagnetics, as indicated by findings that show the tool helped master electromagnetic concepts [40]. Similarly, the development of a computer-based training tool for 2D cross-sections of complex 3D structures [41] and the use of Spartan to support a student-centred activity on alkane conformations both contribute to improved visualization from different viewpoints and better understanding of complex structures [53]. These simulations allow for an exploratory learning approach, where students can manipulate variables and see the immediate effects, thus enhancing their mental rotation and spatial visualization skills [64].

Augmented learning incorporates elements of augmented reality (AR) to enrich the learning process. The augmented reality application for linear perspective principles, which demonstrates how augmented reality can aid in understanding and retaining information about spatial relationships and perspective [42]. By overlaying digital information onto the real world, students can visualize concepts in a more tangible way, bridging the gap between abstract concepts and real-world application [83]. This type of learning is particularly useful in disciplines that require a strong spatial understanding, such as architecture, engineering, and art.

Visual pedagogy emphasizes the importance of visual learning strategies in teaching. It involves using visual elements to teach complex concepts and to foster critical thinking. In the case of understanding corruption through freehand drawings, visual pedagogy enables digital natives to think critically about complex issues [54]. The development of web-based lesson tools for multidisciplinary teaching from university art collections also reflects visual pedagogy [48]. The visual components, such as images and graphics, can simplify the communication of ideas and enhance memory retention [49,50]. This approach caters to visual learners and can be particularly effective in subjects where visual comprehension plays a central role [83].

Spatial training in web-based learning environments focuses on developing the ability to visualize and manipulate objects in space. The digital learning resources for prosthodontic education, as well as investigations into mechanical engineering students' design ability using learning styles, both highlight the importance of spatial ability in professional practice [63]. Regular in-class use and testing of students on spatial content enhance 3D visualization skills and spatial ability [57]. Spatial training is essential in fields such as engineering, architecture, and the visual arts, where the ability to navigate and understand three-dimensional spaces is critical.

5.2 Digital Visual Education

Digital visual education significantly contributes to the improvement of visualization abilities through web-based learning methods by providing students with the necessary skills to interpret, analyse, and create visual content in a digital context. The integration of visual literacy and pedagogy and digital and media literacy into web-based learning curricula allows for a comprehensive educational experience that prepares students for the demands of the modern information landscape [84].

Visual literacy and pedagogy are teaching students not only to understand visual content but also to communicate using visual information. It encompasses the development of critical skills needed to interpret complex visual cues in digital media. Domínguez Romero *et al.,* emphasize critical thinking and visual literacy skills in EFL/ESL classrooms, pointing out that students can improve their critical interpretations and interactions with multimodal texts [23]. This reflects an educational shift towards recognizing the importance of visual literacy in a global, digitally-connected world where visual information is ubiquitous. The work by Guinibert M., which developed a learning model for visual literacy through user-centred design, indicating that a formal educational basis for visual literacy is essential [47]. This is supported by findings across various studies that highlight the importance of integrating visual literacy into the curriculum to foster critical thinking, creativity, and the ability to analyse complex visual data [60].

Digital and media literacy focuses on the ability to access, analyse, evaluate, and create media in a variety of forms. It extends beyond traditional literacy in the digital age to include the skills needed to navigate and create meaning in a world where media is pervasive. Martinez-Cardama S. *et al.,* evaluation of Twitter for collaborative reading projects, for example, demonstrates that digital literacy tools can engage students in improved visual elements (GIFs, memes, pictorial tweets) that foster critical thinking and creativity [50]. Additionally, Steendijk L. *et al.,* showcase innovative didactic designs in visual analytics and literacy in school projects, showing that teachers not only focus on teaching visual analytics but also enable students to demonstrate growing knowledge in a more challenging visual literacy and knowledge construction context [61]. This highlights the increasing importance of teaching students not just to consume digital media, but to understand its construction and to contribute actively to media creation.

5.3 Creative Visual Pedagogy

Creative visual pedagogy through web-based learning facilitates a deeper understanding and improved ability to visualize concepts [85]. Artistic methods and visual learning tools are instrumental in achieving this by providing an interactive and engaging learning experience that caters to diverse learning styles. These methods and tools not only support the acquisition of knowledge but also the application of this knowledge in practical and meaningful ways.

Artistic methods involve the use of art and design principles as a pedagogical tool to foster creative thinking and improve visual literacy [62]. According to the data, such methods include the use of activities like collage workshops, which not only encourage critical thinking skills but also facilitate visual argumentation within architectural education [46]. This hands-on approach enhances students' understanding in an image-rich context, which is vital in fields where visual representation is a key form of communication [51]. Noble K. reported in the study, the incorporation of art museum practices into primary art and design education. Here, practitioner-led action research and art museum training involving teacher feedback and student involvement led to improved teacher knowledge, creativity, and student engagement in art education [44]. This highlights the value of

integrating artistic methods into web-based learning, providing a rich, engaging, and interactive learning experience that encourages students to both understand and communicate complex concepts through visual means.

Visual learning tools encompass a variety of digital resources and methods designed to improve visual literacy and enhance the learning experience [52,86]. Infographic design in higher education, as an example, involves assessing student-produced infographics to reveal insights into students' visual literacy skills for content generation and data visualization [49]. These tools allow students to synthesize complex information into a visually compelling format, which can aid in both understanding and retention of information. Moreover, photography has been identified as a valuable visual learning tool in entrepreneurial education, as it aids students in visual literacy and conceptual development, thereby preparing them for global challenges [58]. The use of visual elements not only helps in the comprehension of abstract concepts but also in the application of these concepts in real-world scenarios. Tools like virtual classrooms and web-based games further contribute to this theme by offering interactive and engaging methods to visualize and manipulate concepts, which is especially beneficial in fields such as engineering, where spatial ability is critical.

6. Conclusion

The integration of web-based learning innovations such as interactive simulations, augmented reality, visual pedagogy, and spatial training has been instrumental in enhancing students' visualization skills. These methods collectively contribute to a more comprehensive and engaging educational experience, accommodating various learning styles and improving students' understanding of complex concepts. Interactive simulations allow students to interactively engage with challenging material, particularly in technical fields [87]. Augmented reality bridges the gap between abstract academic concepts and practical real-world applications, making learning more tangible [88]. Visual pedagogy leverages visual elements to reinforce complex ideas, promote critical thinking, and aid memory retention, proving especially effective in visually-dependent disciplines. Spatial training, on the other hand, is crucial in fields that require navigation and manipulation of three-dimensional spaces. Moreover, the implementation of visual and digital media literacy into curricula prepares students for the digital age, equipping them with essential skills for interpreting, creating, and communicating via visual content [89]. Tools like Twitter and other digital media not only enhance engagement with visual materials but also stimulate critical and creative thinking [50]. These pedagogical approaches ensure that learning transcends mere knowledge absorption, encouraging practical application and innovation. Artistic methods and visual tools provide diverse, interactive learning experiences, readying students for real-world challenges and ensuring they are adept at using their visual literacy skills in various contexts [62].

For future studies may use more databases, such as Eric, IEEE, SAGE and others. Combining all of these datasets may provide interesting and worthwhile findings.

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