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Applying Comics as Learning Tools: A Thematic Review

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Abstract

Comics can improve the experience of educating by making learning more attractive and accessibility. It is important to understand the relationship between comics and education, advancing theoretical knowledge and practical applications of educational research. The objective of this study was to conduct a thematic review on the utilization of comics in education from 2019 to 2023. By using ATLAS.ti 23, a thematic review was composed to examine 33 pertinent articles. Quantitative analysis revealed a growing academic interest in the field, while qualitative analysis identified five main themes: (1) the educational potential of comics, (2) multidisciplinary approaches, (3) science communication and public engagement, (4) promoting equity and inclusion, and (5) technology integration and comics creation. These themes highlight the effectiveness of comics in increasing student engagement, simplifying complex scientific concepts, and promoting educational equity. Although there are these encouraging findings, the study also points to the gaps in actual implementation and evaluation, emphasizing the need for further research. The conceptual framework provides guidance for future research and new direction for researchers and policymakers to utilize comics to promote more inclusive and innovative educational practices. This paper contributes to a deeper understanding of the dynamic interaction between comics and education and provides a framework to guide the future research and practice.

Keywords: Comics, Education, Systematic Literature Review, Atlas.Ti 23.

Introduction

Farinella (2018), e highlights that comics have become an increasingly popular medium for science education and communication in recent decades. Comics have shown their potential to make scientific topics more accessible and appeal to audiences from different ages and cultural backgrounds. The educational potential of comics was recognized early on, and educators and psychologists admitted their value. Noticeably, Sones (1944), suggests to integrate comics into the classroom in the Journal of Sociology of Education. In line with this, many contemporary educators also support the use of comics in education (Farinella, 2018).

Comics are more effective in education than traditional learning methods. As Czerwiec et al (2020), have pointed out, comics are more effective at disseminating information than academic journals. This view is also supported by Bramlett and his colleagues (2016) who similarly argue that comics are superior to medical journals in information-spreading.

Comics as a new educational tool has received much attention in research, but there is an urgent need to explore this phenomenon in depth from different perspectives. This includes exploring the reasons for the increasing number of comics were used in education, the unique advantages of comics, design methods, and the ways and effects of implementing comics in education. It is worth noting that there is still a relative lack of research on comics education, though there has been a gradual increase in the number of studies on comics education. This study can provide more perspectives and directions for future research and help educators and researchers better understand and utilize the potential of comics in education. Thus, it can promote educational innovation and enhance people's learning experience, which will promote the progress and development of education and science popularization fields.

Background Literature

The Communicative Power of Comics

Comics are primarily a "sequential art" McCloud (1993); Eisner (2008), in his work Comics and sequential art states that comics have an inherent ability to effectively communicate processes or procedures due to their continuous narrative nature. Farinella (2018), argues that storytelling may have evolved into a social or moral simulation that is able to better predict the behavior and reactions of others. Comics intertwine narrative and visuals in a way that is consistent with our physiological predisposition to sensory-based perception and memory, thus enhancing memory persistence. Jonsson and Grafström (2021), argue that comics have a communicative and informative effect that facilitates the dissemination and communication of knowledge. In addition, comics contribute to illustration by presenting challenging realities and sensations, especially in the areas of health and medicine (Chute & DeKoven, 2006 ; Williams, 2013). McCloud (1993), believes that iconography is the most important aspect of the comics vocabulary because it represents any image used to depict a person, place, thing, or idea. Icons simplify messaging while eliciting recognition. In addition, comics have the potential to make abstract scientific concepts more concrete through metaphorical means such as anthropomorphism, making them easier to understand for lay audiences. Furthermore, beyond mere comprehension, metaphorical framing has been shown to influence individuals' attitudes towards scientific information and may affect their behavior. Metaphors play a central role in the advancement of science when people are first exposed to new unseen entities, as describing them in terms of the familiar aids' comprehension. Thus, comics are uniquely suited as an educational and communication tool to help learners grasp complex concepts more effectively and achieve knowledge transfer and retention in diverse contexts.

Comic in Education

In terms of practical effects, the relationship between comic books and science popularization begins with the promotion of reading. Since the 19th century, comic books have been used to promote reading and language learning (Dorrell et al., 1995). Since the late 1930s, a number of scholars have explored comics from an educational perspective, for example, as a learning tool. Tatalovic (2009), states that the motivation provided by comics is very effective in

education, social assistance and awareness raising. Comics can be a productive medium for technical communication, including the provision of educational and pedagogical materials. Comic books can stimulate the interest of comic readers and improve their scientific literacy (Aydinoglu & Allard, 2010). Science comics have shown early success in popularizing knowledge, especially in the fields of biology, medicine, and physiology. According to Cheesman (2006), a professor of biology, comic strips help to understand scientific concepts, capture students' attention, introduce new topics, and stimulate critical thinking. A Korean team embedded anatomy knowledge in comics to educate college students about anatomy (Shin et al., 2013). Additionally, comics have been studied for their use in medical education and patient care Green & Myers (2010), and an offshoot called "image medicine," where comics are used to tell personal stories about illness and health, has emerged. Hou et al. (2023) suggested the use of comics to reduce preoperative anxiety in children, suggesting that comics would support and empower children by increasing their preoperative knowledge, which would reduce their levels of preoperative anxiety and potentially help to improve health outcomes.

Overall, comics remain a largely unexplored area, with current academic research, particularly on the conceptual aspects of comics, still needing expansion. Thus, comics are not only an effective form of communication, but also a largely unexplored resource (Farinella, 2018).

Diverse Forms of Comics in Educational

Comics have been used in a variety of educational environments to address different learning styles and goals. Educational comics show in many forms, including digital comics, interactive web comics and traditional print comics. For example, digital comics provides interactive functions such as clickable links, animations, and quizzes which can enhance student engagement and provide immediate feedback(Craciun & Bunoiu, 2019 ; Tatalovic, 2009). In addition, they can include multimedia elements such as audio and video to provide more contexts for learning complex concepts (Hou et al., 2023). In addition, interactive webcomics can be reorganized according to the reader's choices, creating a more immersive learning experience(Shin et al., 2013 ; Green & Myers, 2010). On the other hand, traditional printed comics, while lacking interactivity, are still popular due to their accessibility and easy to use in the classroom (Farinella, 2018 ; Cheesman, 2006). Each form of comics has its unique advantages. It can be chosen according to the educational objectives and the needs of the learners.

The flexibility of comics allows them to be integrated into a wide range of disciplines, from science and math to history and social studies. For example, educational comics teach environmental science by showing the effects of human activity on ecosystems (Vasileva & Golubev, 2019). In the field of history, comics can bring historical events to life and help students visualize and better understand the past (Moreno-Vera et al., 2021). Comics also help develop critical thinking and problem-solving skills; by presenting situations that require students to analyze information and make decisions, comics encourage active learning and engagement. It is proven that this approach improves students' ability to apply their knowledge in real-world situations(Aydinoglu & Allard, 2010).

Thesis structure

This paper reviews the literature on comics education from 2019-2023 to identify trends in comics and education and their interrelationships. The focus is on how comics can be used for education.

In order to achieve the research objectives, this paper is divided into four parts. The first part discusses the current state of research on utilizing comics in education and presents the research questions. The second part focuses on the research methodology of this study, the procedures of data collection as well as analysis. The third part analyzes the findings of 33 articles using quantitative and qualitative methods respectively, focusing on five key themes: (1) Educational Potential of Comics, (2) Multidisciplinary Approach, (3) Science Communication and Public Engagement, (4) Promotion of Equity and Inclusion, and (5) Technology Integration and comic creation. In the fourth section, this paper presents a framework for utilizing comics in education. Lastly the paper presents the conclusions of this study and suggests future research.

Materials and Methods

Clarke and Braun (2006), proposed a definition of thematic analysis as the process of identifying patterns and constructing themes through an in-depth reading of the subject matter, which helps to understand the trends in research related to the use of comics for education in recent years. Thematic analysis will be used in this study, and the benefits of thematic analysis are that it is an easy to use, flexible and valuable research tool that has the potential to provide a detailed and informative description of the data, as well as providing terminology and a "recipe" for thematic analysis in a theoretically and methodologically sound manner (Braun & Clarke, 2006).

The purpose of this review is to analyze and explain current studies and research related to manga education. Although the use of comics for education was proposed a long time ago, the use of comics for education has only gradually gained attention in recent years. Therefore, the thematic review was prepared according to the procedure introduced by Zairul (2020); and Qiu (2024), capturing those key data related to the research questions through themes that represent some level of patterned responses or meanings in the dataset. This study was dedicated to analyzing and interpreting the findings and making recommendations for future grounded theory in comics education. Literature was selected based on the following criteria: (1) published in 2019-2023; (2) keyworded with at least "comic" or "visual storytelling" and "education"; and (3) associated comics with education. A systematic methodological framework was used in this study, starting with the formulation of the research question, the selection of data sources, retrieval and pre-processing, followed by the extraction, analysis and generalization of themes, and finally the visual presentation, interpretation and discussion of the results.

The literature search was conducted in two major databases: the Web of Science and SCOPUS. Applying the inclusion and exclusion criteria initially yielded 143 articles from the Web of Science and 121 articles from SCOPUS. After filtering out articles that did not align with the study topic and removing duplicates (n=6), including one inaccessible paper and another restricted to non-English language, the final selection was narrowed down to 33 relevant

articles. These articles were then uploaded to ATLAS.ti 23 for further processing (Table 1 and Figure 1).

Table 1
Search string.

Database	Search Strings	Results
Web of Science	Abstract: ('comic') OR ('visual storytelling') AND 'education' and English (Language) and Arilcles OR Editorial Materials (Document types) 2019-2023 (Publication Years)	143 results
Scoupus	TITLE-ABS-KEY ('comic') OR TITLE-ABS-KEY ('visual storytelling') AND TITLE-ABS-KEY 'education' AND LANGUAGE (English) AND PUBYEAR >2019 AND LIMIT-TO (DOCTYPE, 'ar')	121 results

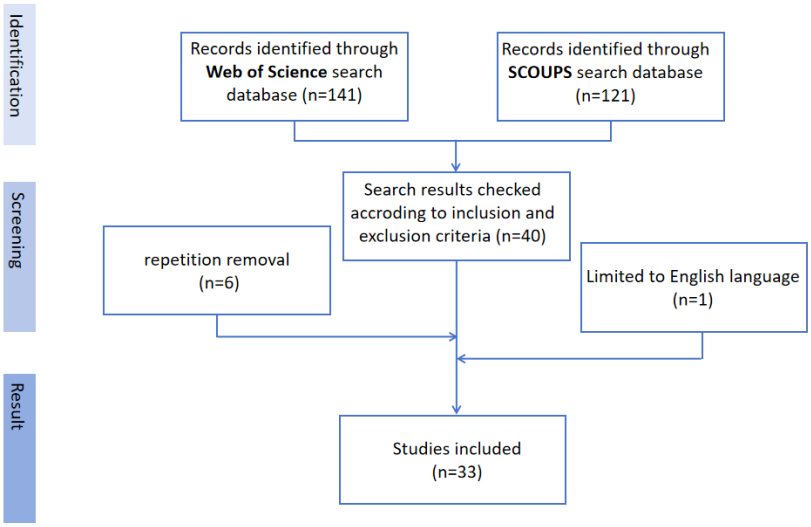

Figure 1. Inclusion and exclusion processes in the thematic review

Subsequently, the article was evaluated using quantitative and qualitative analysis. The quantitative part of the analysis reported the findings mathematically to derive the appropriate data. Meanwhile, the qualitative part extracted codes from the collected essays to summarize the themes and create a conceptual framework.

Results and Discussion

In this section, qualitative and quantitative analysis will be used to analyze the 33 articles and answer the research questions.

Quantitative Results

By analyzing word frequency, year of publication, place of study, and topic can side by side reflect the research trends and research hotspots related to comic book education. First, the following word cloud was generated through quantitative analysis. As shown in the word cloud, the most frequent words are comics, students, science, education, knowledge, information. As previously mentioned as the research focus of this paper, the high-frequency words show the main terms of the topic. The word comics was mentioned 2573 times, followed by students and science which were mentioned 1803 and 1751 times respectively,

and finally Education, Information and Knowledge were mentioned 1435, 687 and 594 times respectively.

By analyzing word frequency, year of publication, place of study, and topic, it is possible to partially reflect the research trends in cultural heritage related to souvenirs. First, the quantitative part generated the following word cloud based on the analysis of the primary literature (Figure 2). As shown in Figure 2, the most prominent words appearing in the word cloud are 'tourism', 'culture', 'cultural', 'heritage', 'value' and 'tourist', which suggests that these words appear frequently in the articles. As mentioned earlier, this article focuses on souvenirs related to cultural heritage. The word cloud shows the main terms used for this theme, where the word 'tourism' was mentioned 1656 times, followed by 'culture' and 'cultural' with 1440 and 540 mentions respectively, while 'heritage', 'value' and 'tourist' were mentioned 1062, 733 and 711 times respectively.

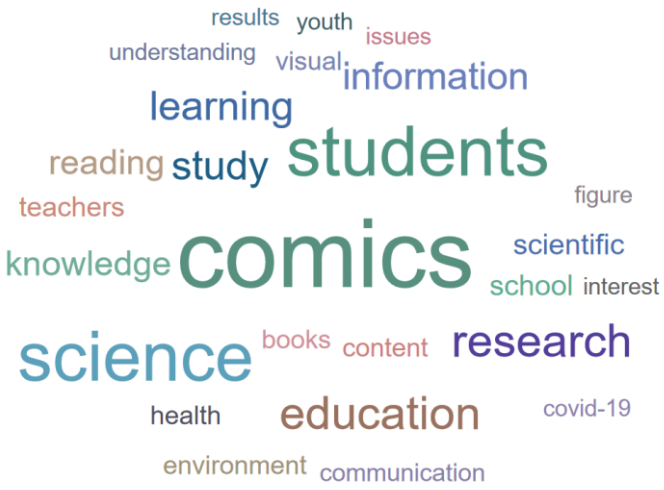

Figure 2. Word cloud generated from 33 articles.

Figure 3 shows the number of publications related to this theme. 5 in 2019, 3 in 2020, 3 in 2021, 10 in 2022 and 12 in 2023. The overall trend for this topic is upward, starting with fast growth in 2022 and peaking in 2023. Comics are being used more as an educational tool and are receiving attention from scholars.

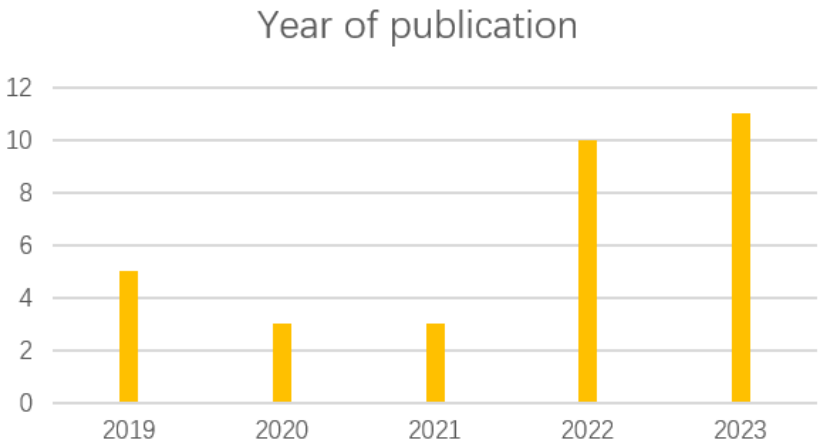

Figure 3. Year of publication.

Figure 4 presents the results of a preliminary analysis of the geographical distribution. In terms of study regions, research on the use of comics for education involves multiple countries and regions, covering the Americas, Europe, Asia, Africa, and Oceania. Countries such as the United States, the United Kingdom, and Canada have had related studies over multiple years, showing the continued interest in comics education in these countries, with studies focusing on how to better apply comics to explore new educational models and methods. For example, Matuk et al (2021), examined how educators used a series of comics to engage diverse students in virology, exploring their strategies and challenges in promoting equitable science teaching through the dynamic relationship between teachers and tools such as comics. Tavares et al (2023), explores the use of comics creation to tell the story of NAFLD through a collaboration between researchers and artists, demonstrating how visual metaphors and a multimodal approach can simplify complex scientific concepts and promote scientific and health understanding.

Studies in developing countries usually focus within specific years, such as Malaysia and Russia in 2019, Uganda in 2022, and Indonesia in 2023. Research in these countries tends to address specific educational and social issues, such as health education, cultural transmission, etc. (Abrori et al. ,2024). To improve education in North Kalimantan, Indonesia, motivated teachers to utilize comics with SSI content as a means of raising reading standards. Logie et al (2022), in Uganda utilized comics for refugee youth to examine the effectiveness of HIV self-testing kits in increasing the frequency of HIV testing and improving HIV knowledge.

On the other hand, there is also the Jirásek (2021), who analyzed the potential of comics in informal education for holistic personality development by promoting physical activity, moral values and a sense of adventure. Moreno-Vera et al (2021), from Spain, found that teachers found teaching history with comics to be more stimulating and creative than using textbooks. In multidisciplinary teaching, similar studies conducted by scholars from Turkey and Germany proved that comics have a significant positive effect in environmental protection education.

Overall, research on comic education has expanded from developed to developing countries, demonstrating the widespread use and recognition of this educational tool globally. Both developed and developing countries are constantly exploring the use of comics in different educational fields, covering a wide range of areas such as health education, cultural communication and social issues.

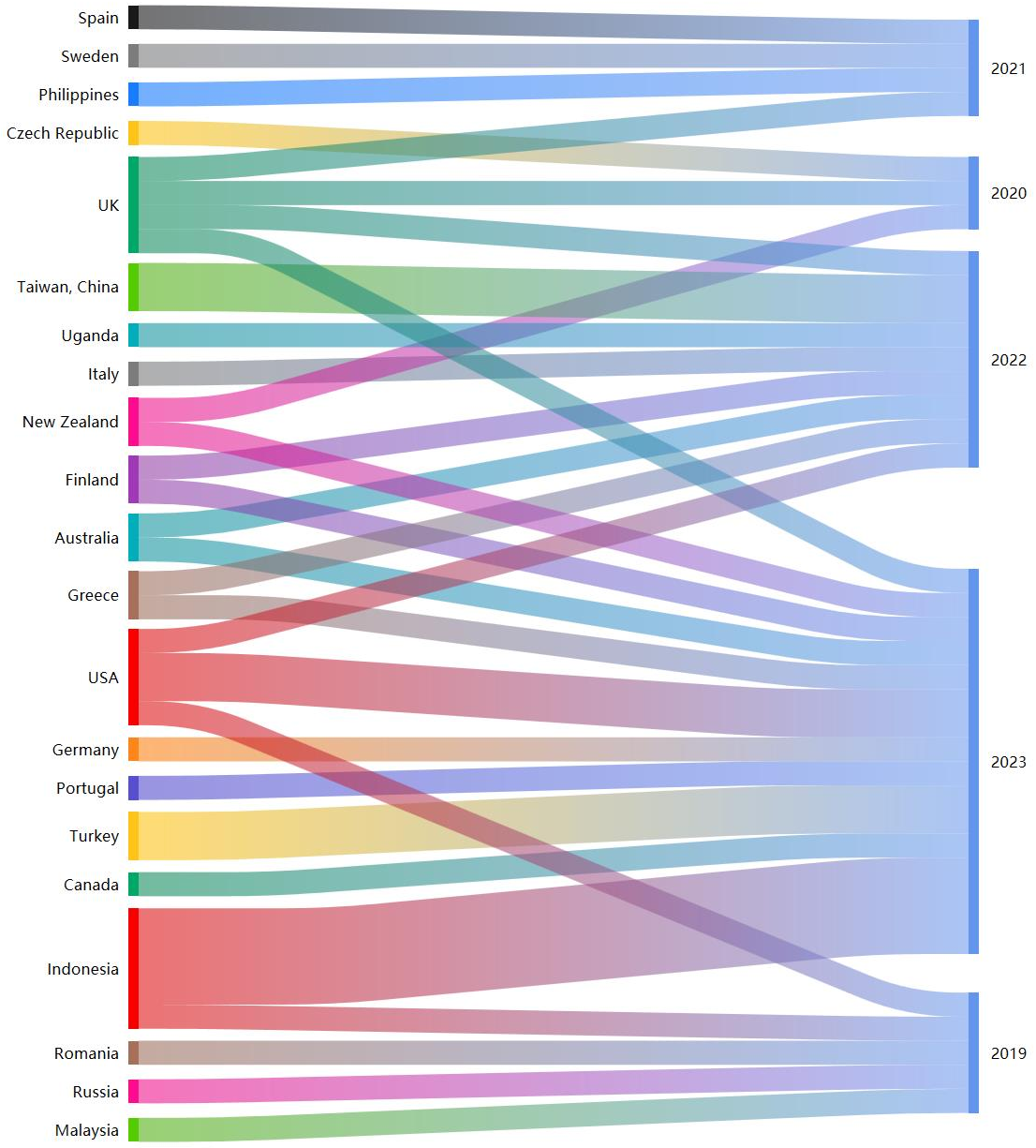

Figure 4. Countries of studies and years of publication with the number of articles.

Thematic trends and patterns are highlighted in Table 2 below. Initially there were eleven coded attributes, but after merging and renaming, the final coding was reduced to five themes; Educational Potential of Comics, Multidisciplinary Approach, Science Communication and Public Engagement, Technology Integration and comic creation, and Promotion of Equity and Inclusion. These five themes will be analyzed in detail later in the qualitative section. Many of the selected articles focus on examining the potential of comics in education as well as technology integration and creation methods for comics. The themes of science communication and public engagement are also important research concerns. And the themes of multidisciplinary approaches and comics for equity and inclusion are mentioned almost every year.

Table 2
The theme according to year.

	2019	2020	2021	2022	2023	Total
Educational Potential of Comics	2	1	2	2	5	12
Multidisciplinary Approach	2	0	2	0	1	5
Promotion of Equity and Inclusion	1	0	0	2	1	4
Science Communication and Public Engagement	0	2	1	4	2	9
Technology Integration and comic creation	3	0	0	0	7	10
Total	8	3	5	8	16	40

Overall, this section reveals trends in comics education research through a quantitative research structure. To some extent, these results reflect the wide range of applications and potential of comics in education. Although these studies have emphasized the role of comics in promoting students' interest and enhancing the public's willingness to engage in science learning, few studies have delved into the specific design methods of comics and how researchers or teaching staff can effectively collaborate with artists. Future research should focus more on these aspects in order to more fully understand and optimize the use of comics in education.

Qualitative Results

This section is a qualitative analysis that explains the themes that emerged from answering the research questions after reading the relevant articles. Each article was first coded thematically, and then all codes were summarized and integrated to identify the researcher's thinking and the theories and concepts that were studied. Five themes were ultimately identified: (1) Educational Potential of Comics, (2) Multidisciplinary Approach, (3) Science Communication and Public Engagement, (4) Promotion of Equity and Inclusion, and (5) Technology Integration and comic creation. These themes do not stand alone, but may overlap between articles, so some articles may address several themes at once. In the following section, each theme is explored in depth to answer the research questions and to establish a conceptual framework for using comics in education.

RQ: What are the current trends discussed in the literature regarding the use of comics in education between 2019 and 2023?

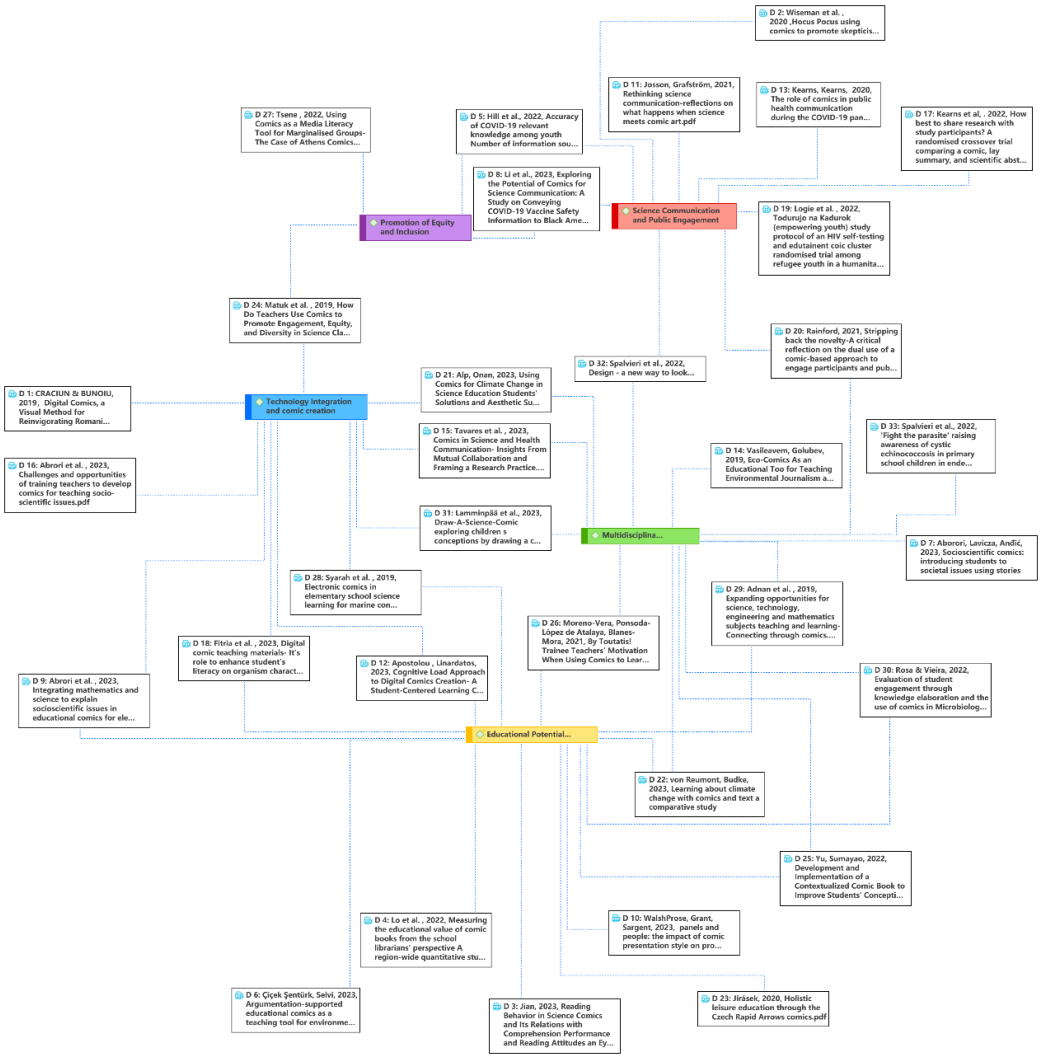

Figure 5. The whole Network.

Theme 1 ：Educational potential of comics

The potential of comics in education is manifold, and he is being increasingly recognized in both formal and informal learning environments. Various studies have shown that the use of comics as a teaching tool facilitates the process of learning to teach. When viewed using constructivist learning theory, visual images in comics (e.g., pictures and photographs) can be viewed as nonverbal representations, consistent with specific learning theory. This implies that visual images play an important role in learning (Yu & Sumayao,2022). Adnan et al., (2019) argued that comics can establish a positive affective context, stimulate students' interest in pedagogical theories, and encourage students to be constantly reflective, think critically about learning, and engage in practice. This experimental study also found that teachers' use of humor pedagogy in the classroom enhances students' enjoyment and acceptance. In addition, the narrative structure inherent in comics promotes engagement and immersion, encouraging readers to actively participate in the learning process. The use of materials such as stories is important in teaching content to students, and by creating experience-based environments, students can acquire knowledge structures both cognitively and experientially (Alp & Onan, 2023). Besides learning by reading comics, students can also create comics. In this process, it is possible to discover the most central aspects of the subject being studied and to re-present them in a new form. Linardatos (2023) also mentions that students regarded the creation of

comics as an enjoyable and accessible way of learning. According to Jirásek (2021), comics play an important role in promoting literacy, language acquisition, and social-emotional learning as well in addition to traditional academic subjects. Comics have become an effective tool to reach the physical, mental, social and spiritual dimensions and promote holistic self-education. The strong connection between comics and non-formal education can be clearly demonstrated by examples such as the Czech comic strip "Fast Arrow". By using the creative and interactive potential of comics, educators can accommodate different learning styles and preferences, making learning more inclusive and accessible to all students. Overall, the educational potential of comics goes far beyond entertainment, providing innovative and effective ways to engage learners and promote meaningful learning experiences.

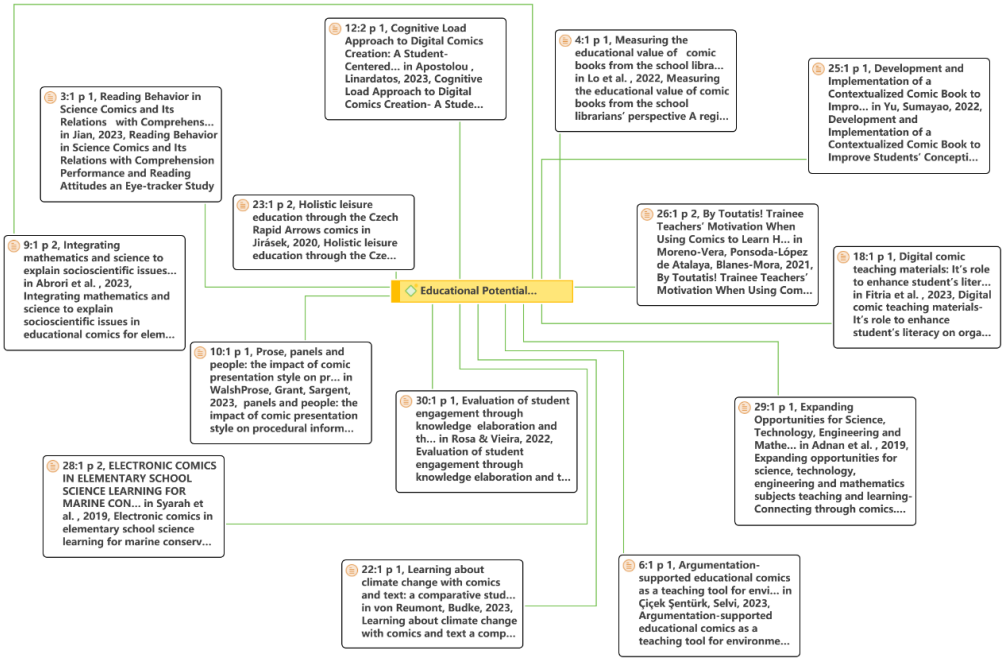

Figure 6. Network of Educational Potential of Comics.

Theme 2 : Multidisciplinary Approach

Comics have become a multifunctional and engaging medium that transcends traditional disciplinary boundaries, making them into a valuable tool for facilitating interdisciplinary learning experiences. For example, in the field of history, reading comics enables students to develop the necessary framework for historical thinking. It stimulates interest in history learning in a way which is difficult to achieve with traditional textbooks. Comics encourage critical thinking and inspire creativity in students, which facilitates the learning of history (Moreno-Vera et al., 2021). Similarly, in science education, comics can be used as an effective tool to explain complex scientific concepts and processes. Tavares et al (2023), argued that comics, as educational and promotional tools for health promotion, can help people understand complex medical concepts. Vasileva & Golubev's experimental research shows that comics help students by using visual diagrams, character interactions, and storytelling techniques to visualize abstract scientific principles and understand their real-world applications. Comics are an effective tool for developing visual scientific literacy and constructing persuasive arguments. Comics can provide students with wings of imagination and help them develop creative thinking. Yu & Sumayao (2022), suggest incorporating comic books into the teaching of science concepts. Especially for those science concepts that are

considered difficult or complex, as well as those science skills are believed to be the most difficult to master.

Additionally, comics can promote interdisciplinary connections by integrating multiple subject areas into a consistent narrative. For example, comics with an environmental theme could incorporate elements of biology, chemistry, geography, and social studies, encouraging students to explore the interconnections between scientific concepts and societal challenges. In Alp and Onan's (2023), study, students present cartoons with important solutions to global climate change, pollution, destruction of the natural environment, and extinction of living things. These include measures to prevent global warming, make peace with nature, and protect the soil. Through the use of comics, students are taught to develop decision-making skills, creativity, autonomy and teamwork, promoting self-regulation and educational development from the individual to the societal level. In addition, learning through comics enhances students' aesthetic skills while engaging them in meaningful learning experiences.

By adopting a multidisciplinary approach to the use of comics in education, educators can develop students' critical thinking skills, foster a deeper appreciation for different subject areas, and enable to make meaningful connections between different areas of study.

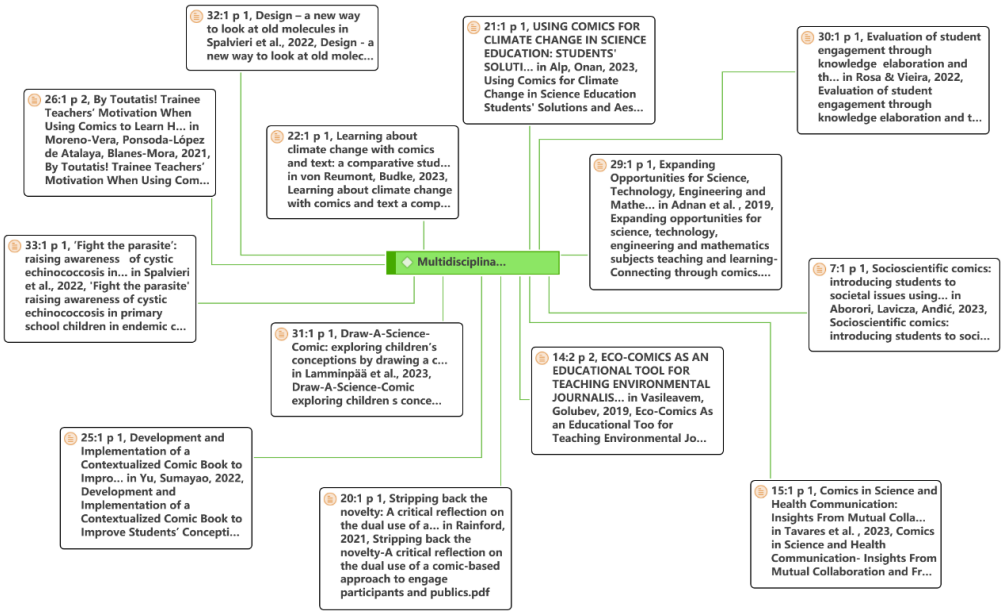

Figure 7. Network of Multidisciplinary Approach.

Theme 3 ：Science Communication and Public Engagement

As a familiar entertainment medium, comics are popular and loved by a wide audience. It is easy to share and spread information effectively on social media (Kearns & Kearns, 2020). Comics have become a multipurpose and influential medium for science communication and public engagement, contributing not only to the dissemination of scientific knowledge but also to meaningful dialogues between different audiences. From promoting suspicion of pseudo-scientific claims (Wiseman et al., 2021) to conveying critical information about global health crises such as the COVID-19 pandemic Li et al (2023); Hill et al., (2022); Kearns & Kearns (2020),comics provide a visually engaging and easily accessible platform for engaging readers and facilitating wise decision making (Rainford, 2021). Research has shown that comics can effectively communicate complex scientific concepts in an immersive and relatable way,

enhancing knowledge comprehension and memorization and facilitating the change of attitudes. By integrating narrative and visual material, comics can effectively address learners' affective and cognitive barriers and enhancing the memorization and retention of scientific facts(Li et al., 2023). For example, a study by Hill et al (2022), investigated the use of comics to deliver COVID-19 knowledge to adolescents and the results showed that participants who were exposed to comics-based educational materials had significantly higher rates of knowledge accuracy. Additionally, comics have been used to disseminate vaccine safety messages to specific communities (e.g., African Americans) (Li et al., 2023), highlighting the importance of cultural relevance and inclusive science communication strategies.

The advantages of comics in cross-cultural communication should not be ignored. Comics can be used as a medium for presenting science in a graphic narrative that utilizes the power of visuals, text, and storytelling to overcome barriers of language, knowledge, age, and culture (Kearns & Kearns, 2020), and to communicate scientific information to readers from different backgrounds and languages. It is particularly important for global science communication, especially in multi-linguistic environments. For example, in public health communication, the use of comics to reach communities with different cultural backgrounds can ensure the accuracy and acceptability of the information. Jonsson & Grafström (2021), believe that through the cooperation between scientists, artists, and educators, comics have the potential to transform science communication by re-imagining the ways in which scientific information is shared, understood, and applied in society.

Moreover, comics promote public engagement. With the interactive content, such as the magic shows in comics Wiseman et al (2021), readers are not only a passive recipient of information, but also an active participant. This interactive form increases reader engagement and makes science communication livelier and more interesting. In addition to traditional science communication, comics have been used to address broader public health challenges, empower marginalized communities, and share research findings with research participants in an accessible and engaging format (Kearns et al., 2022).

By using the power of visual narrative, humor, and creativity, comics make science more accessible and engaging for all people. In summary, comics, as a science communication tool, have multiple advantages such as simplifying complex concepts, emotional attraction, enhancing participation and cross-cultural communication, with great potential in promoting scientific knowledge popularization and public participation.

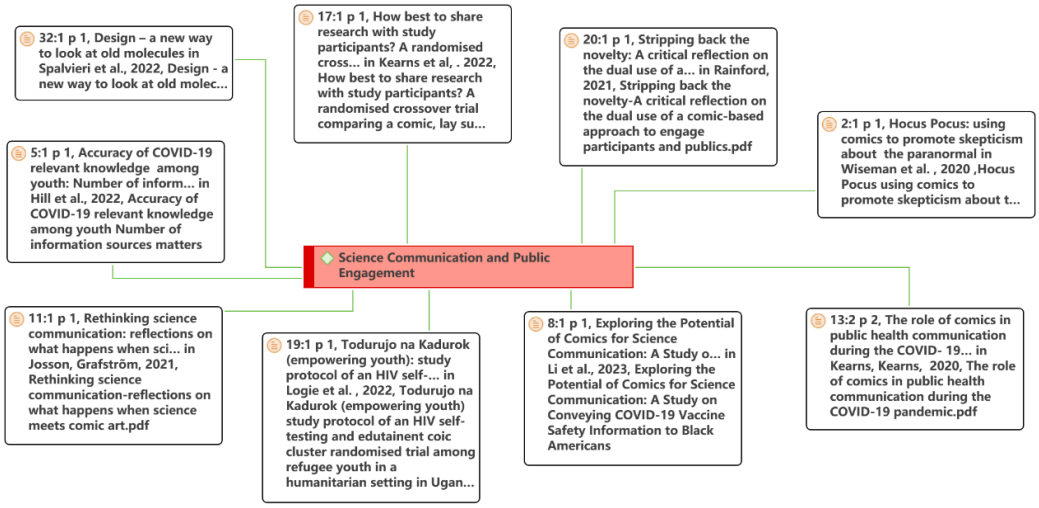

Figure 8. Network of Science Communication and Public Engagement.

Theme 4 ：Promotion of Equity and Inclusion

Equity means that all learners, no matter their differences, have the same opportunity to succeed. However, unfairness appears when some groups enjoy more chances of success than others due to differences in social status and opportunities to access resources (Unterhalter, 2009). Archer et al (2012), proposed a theory of science capital based on Bourdieu's social capital theory Bourdieu (1984), to describe the different ways in which adolescents gain science experiences through their parents, schools, and communities. Unequal access to science capital leads to unfair identification of teenagers with science in early adolescence, influencing the formation of attitudes about the utility of science in their lives, health, future careers, and society. Comics, as a multi-modal text that requires creators to co-ordinate different media and genres, creating opportunities for students to make connections to knowledge learned at school, at home, and in the larger community (González, Moll, & Amanti, 2005; Matuk et al., 2021). At the same time, it has a strong ability to transfer knowledge learners even the slowest one (Tsene, 2022). This type of learning across multiple environments helps to reduce inequities in education and promotes equity and inclusion in education by including students of all backgrounds and abilities in the learning process.

Research has shown that comic books can work as effective teaching tools. they can be uniquely successful in helping teachers address issues of diversity, equity, and engagement in science learning if they are used appropriately (Matuk et al., 2021). Through the use of comics, teachers are able to introduce diverse pedagogical methods that capture students' interest, increase their engagement, and help them overcome obstacles they may have encountered in traditional teaching environments.

On the other hand, with the turnover of all types of social media, we are surrounded by an era of misinformation/disinformation and fake news. The vulnerable groups such as refugees and other marginals are even more vulnerable. The arrival of Covid-19 in particular not only brought us an epidemic virus, but also digital inequality as some groups were excluded by the digital transition. And the sharing of information in comics is a key factor in the dissemination of scientific information to racial minority groups. Compared to traditional forms of information, comics are able to deliver scientific information more effectively and enhance the usefulness and attribution of the information due to their visual appeal and storyline

(Farinella, 2018). In addition, cartoonization and non-figurative characters in comics allow viewers to identify with the characters regardless of their age or other identifying characteristics (Scott McCloud, 1993. By focusing on diversity and using recognizable characters, comics can create a shared space that facilitates discussion and knowledge transfer (Humm & Schrögel, 2020), and thus exposure to comics can increase social sharing of scientific information among underserved audiences (Li et al., 2023). For example, the Athens Comics Library utilizes comics to provide inclusive media literacy education for refugee populations, fostering creative thinking, content creation, collaboration, and empathy (Tsene, 2022).

Comics serve as a creative and innovative way to address these inequalities and create a more inclusive education system where all different groups have access to information as well as knowledge to adapt to the current changing environment (Tsene, 2022). Comics not only simplify complex concepts, but they also resonate with readers through vivid storytelling and characterization, stimulate curiosity and critical thinking, and promote social change. Thus, comics have great potential as an educational and social justice tool.

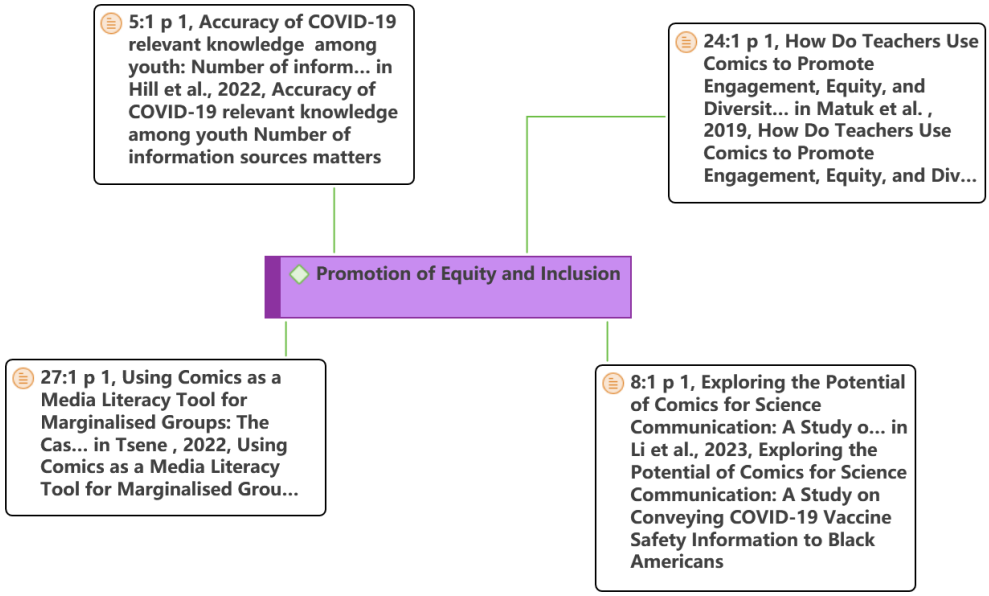

Figure 9. Network of Promotion of Equity and Inclusion.

Theme 5 ：Technology Integration and Comic Creation

Technology integration

The integration of technology plays an important role in education by providing a platform for students to blend their creative and technical skills. Through the use of digital tools and software, students are able to create more freely, thus stimulating their creativity and improving their technical skills. For example, in the reform of science education in Romania, digital comics were used as a medium for science education and communication, and by creating comics using ICT tools, students not only stimulated their interest in learning, but also improved their scientific literacy (Craciun & Bunoiu, 2019). Linardatos (2023), also proves that digital comic creation motivates students to select only the necessary information from the curriculum, express it in their own words, and reorganize it using the knowledge they already have. Secondly, the use of technology enhances the interactivity of education and becomes more engaging. Digital comics are based on electronic digital formats that can display coherent storylines, games, movies and animations, and other applications can be inserted to

make it easier for readers to follow and appreciate each story (Fitria et al., 2023). Through the use of digital platforms, instructional materials can be transformed from static visual art forms to dynamic, multi-sensory experiences. These technologies allow readers to engage more deeply in the learning process, enhancing their immersion and engagement. In the study by Fitria et al (2023), students were very interested in the use of digital comics and had increased interaction with the teacher in their learning. Students could play and learn at the same time and achieve their learning goals. Again, digital technology also supports collaboration and sharing among students. Through online platforms and social media, students can share their work with peers and teachers, receive feedback and make improvements. This collaborative learning model not only facilitates the exchange and sharing of knowledge, but also enhances students' teamwork and social skills (Abrori, Saimon, et al., 2023). Finally, e-comics are considered efficient because, like print media, they eliminate the long marketing distribution path from publisher to retailer. Its high mobility is also a compelling point, i.e., it can easily carry a dozen or more materials in a single application (Syarah et al., 2019). In this digital age, almost everyone is a native of the internet, especially students. Hands-on learning activities based on Information and Communication Technology (ICT) tools aim to increase students' interest in science in both formal and informal education. In this context, the use of visuals and ICT, especially digital comics, can be a suitable medium and method of science education and communication for the younger generation (Craciun & Bunoiu, 2019).

Comic creation

As comics research becomes a growing field, researchers are utilizing the medium more. However, comics as a research practice/methodology has received little attention, particularly the research frameworks for comics production (Tavares et al., 2023). In order to ensure effectiveness in educational settings, scholars have argued that comics creation needs to refer to certain theoretical and practical frameworks. Abrori et al. (2023)combined the TRACK framework Graham (2011), and comics theory McCloud (1993), in comics creation. Technological knowledge refers to the ability of teachers to develop comics using digital technology, while content knowledge refers to their proficiency in driving pedagogical content in comics. Abrori, Prodromou et al (2023), utilized the 'Rule-of-Five' framework in their research Diaz Eaton; Highlander & Schugart (2019), which integrates multiple disciplines into the comics content. The framework addresses empirical, linguistic, numerical, visual, and symbolic representations to make complex concepts more accessible and engaging for students.

Teachers are trained to develop comics that combine scientific knowledge with engaging narratives. Includes carefully crafted characters, storylines, and educational content to ensure the clarity and engagement of the comic. For example, introducing characters at the beginning of a story with unique visual depictions and background stories helps students connect with the characters and follow the narrative effectively (Abrori, Saimon, et al., 2023). In addition, Linardatos Linardatos (2023), also proposed the principles of coherence, signaling, redundancy, spatial and temporal continuity, segmentation, pre-training, modality, multimedia, and personalization to optimize the creation of comics and reduce the cognitive load on students.

On the other hand, comics can be created by using a variety of digital tools and platforms. Tools such as Krita, MediBang, Canva, Pixton (CRACIUN & BUNOIU, 2019), and ComicsFun

(Linardatos, 2023) are commonly used for digital drawing and comics creation. These platforms offer functions that allow users to create detailed and visually appealing comics without extensive artistic skills, thus making comics accessible to a wider range of educators and students.

Challenges and Opportunities

Integrating comics into education has many benefits, but it also comes with challenges. Such as compatibility issues with computer equipment and lack of digital drawing ability (Abrori, Saimon, et al., 2023). However, with adequate object support, such as the use of well-equipped computer labs and stable Internet connections, improving the comic creation platform, and adding more models, these obstacles can be overcome and create an conducive environment for comic creation. In addition, cartoonists can cooperate with researchers and share their ideas with each other in order to improve the accuracy and educational effectiveness of comic (Tavares et al., 2023 ; Spalvieri et al., 2022)..

Overall, digital comics provide a promising way to enhance science education by combining the advantages of visual narratives and digital technology. By addressing the challenges and Take advantage of opportunities, educators can create a dynamic and interactive learning environment that fosters student interests and understanding of complex scientific concepts.

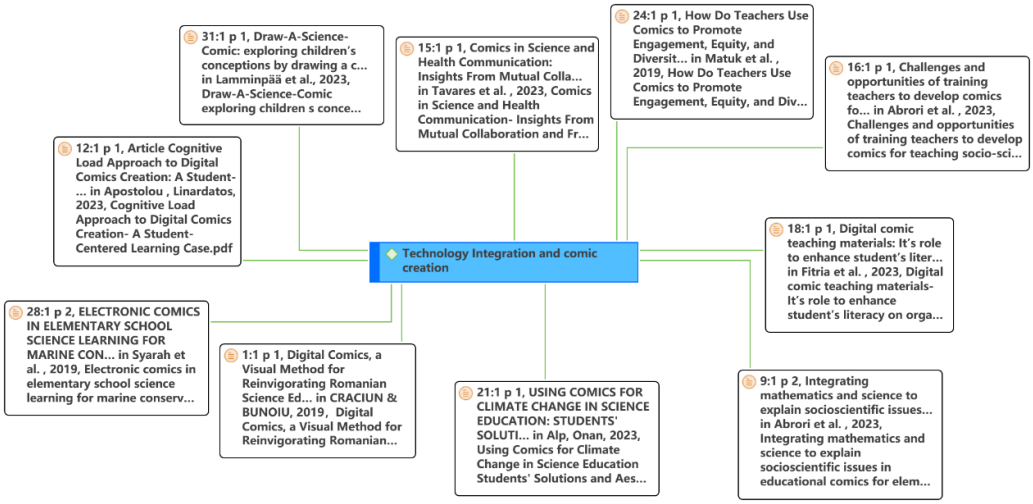

Figure 9. Network of Promotion of Technology Integration and Comic Creation.

A Conceptual Framework for Education Comics

Through an analysis of the literature and a review of the research, this paper presents a conceptual framework that provides recommendations for future work on the use of comics in education. Figure 10 illustrates five key future research directions to guide the way in which comics are used in education. This helps to identify new research opportunities, provide strategic support to educational policy makers, and promote practical approaches to instructional design. The framework describes the theories and concepts related to comics creation, technology integration, student learning, and educational equity, respectively, while constructing their logical relationship to enhancing educational outcomes. Given current research trends, the following categories are possible directions for future research:

① Educational Potential of Comics: An in-depth discussion on the specific applications of comics in different disciplines and educational levels and the evaluation of their effectiveness.

② Multidisciplinary Approach: Research on how manga can incorporate multidisciplinary content to promote students' interdisciplinary learning and comprehensive abilities.

③ Science Communication and Public Engagement: analyzing the role of comics in science communication, especially their effectiveness in increasing public understanding and engagement with healthcare and science topics.

④ Promotion of Equity and Inclusion: Exploring strategies and examples of comics promoting equity and inclusion in education to help reduce educational inequality.

⑤ Technology Integration and comic creation: research on the application of digital tools and platforms in comic creation to enhance creative efficiency and content quality while addressing technical challenges.

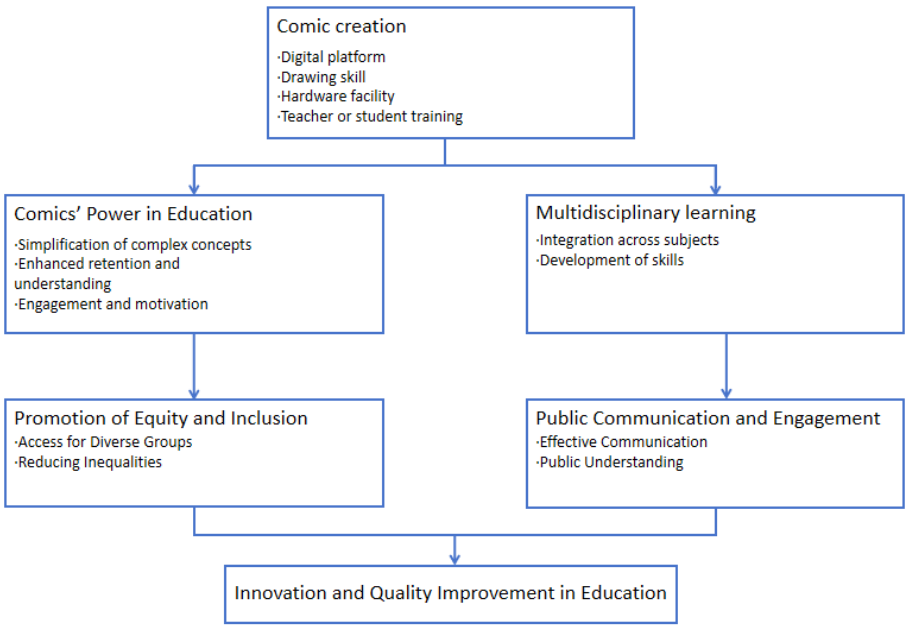

Figure 10. A conceptual framework for improving the educational power of comics.

Conclusions

Finding

This paper reviews 33 literature articles on the use of comics in education between 2018 and 2023, outlining the current state of research and trends in the field. Analyzed through the ATLAS.ti 23 software, the quantitative results show a lack of systematic review articles, despite the gradual increase in academic interest in the topic. Despite the progress of research in this area in recent years, there are still shortcomings in terms of concrete implementation and evaluation, partly due to the failure of policymakers and educational practitioners to fully recognize the role of theory in guiding educational innovation. In its qualitative analysis, this paper highlights five key themes that have emerged from the literature: the educational potential of comics, multidisciplinary approaches, science communication and public engagement, promoting equity and inclusion, and technology integration and comics creation. The paper explores the interrelationships of these themes and their implications for educational practice, and makes recommendations for future research to further enhance the effectiveness of comics in education. Through an in-depth analysis of these themes, this paper provides educators, researchers, and policymakers with valuable insights aimed at promoting

the effective use of comics in education and fostering more inclusive and innovative educational practices.

Limitation

Although this paper provides a thematic review and in-depth analysis the field of comics education, there are some limitations that need to be pointed out. First, the literature search for this study was limited to articles published between 2019 and 2023. This may have missed relevant and important studies published earlier than this period, thus limited the results of the study. In addition, this paper relies solely on the Web of Science and SCOPUS databases. Although these two databases cover a wide range of topics, it is still possible to miss relevant studies in other databases.

Secondly, this study relied on the findings in the existing literature during the analysis process, which may have been influenced by the researcher's subjective bias. Although effort was made to remain objective and comprehensive, the potential bias in the process of literature selection and thematic coding could not be completely excluded.

Finally, due to the nature of the literature review, the conclusions and recommendations of this paper are mainly based on the analysis of existing literature and lack of direct data support to validate empirically future research on comics education. Future research should incorporate empirical studies to validate the theoretical and practical recommendations suggested in this paper and to promote the application and development of comics in the field of education.

In summary, although this paper provides important insights into the study of comics education, its limitations still suggest the future study need to be further deepened and expanded.

Future Research Directions

Future research should further explore the diverse applications of comics in education and their impact. First, larger empirical studies are necessary to verify the effectiveness of teaching comics in different educational environments. Second, the use of comics in interdisciplinary teaching should be examined. Exploring how it can be useful in integrating multiple disciplines such as science, math, history, and art. Besides, researchers can deeply analyze the impact of comics among students of different ages, especially the potential benefits for lower grades and special education students.

With the integration of technology, the use of advanced digital tools and platforms to enhance the process of creating comics should be investigated and assess the learning outcome under the impact of these technologies It is also essential to explore further feedback on the experience. Researchers should develop and test feedback systems to understand students' experiences and feelings about reading comics in order to enhance the effectiveness of education by improving teaching methods. In addition, it is important to assess the long-term effects of comic book teaching and analyze its impact on students' knowledge retention, depth of understanding, and attitudinal change.

Finally, comic books should be further explored as a strategy to promote equity and inclusion in education, exploring how student from diverse cultural and social backgrounds can be better served through comic. Through these studies, more comprehensive theoretical support and practical guidance can be provided for the application of comics in education to promoting educational innovation and improvement.

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