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INTRODUCING BIOLOGY THROUGH COMICS: BIBLIOMETRIC ANALYSIS MAPPING

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Abstract: *Using comics with biological content is an art method that is gaining popularity, but it is still uncommon. In contrast, the advancement of biology comics research is still infrequently reviewed by researchers. Based on this, this paper evaluated biology comics research using bibliometric analysis based on the Scopus database. We coded using numerous criteria, including documents and citations, as well as the dimensions of biology comics based on three timeline groupings (2011-2014, 2015-2018, 2019-2022). Based on documents and citations, we grouped them by top journals, top authors, and keywords that were mentioned the most by authors. Based on the dimensions of biology comics research, we examine research methodologies, research samples, biology topics, comics type, comics implementation, and comics roles. In the last part, we reflected on and described potential future research directions based on the collected information.*

Keywords: *biology, comics, bibliometric analysis*

Introduction

Like other branches of the natural sciences, biology uses images and text to explain complex concepts. Images, especially those included in printed texts, have a key role in disseminating biological knowledge (Roth & Pozzer-Ardenghi, 2013; Strouse et al., 2018). In a significant way, they affect the readability and comprehension of the text (Waxman et al., 2014). However, many issues arise when students struggle to connect the text and the visuals in their biology texts (Torrens & Barahona, 2012; Tsui & Treagust, 2013).

As a means of bridging the gap between written and visual representations, some scientists have created comics (Diamond et al., 2021; Morel et al., 2019). Comics allow for a more natural flow of ideas than do more standard explanations with mere graphics (Jacobs, 2007; Low, 2012). Comics are effective in biology education for improving students' comprehension of visual representations like pictures and graphs (Bach et al., 2016). Additionally, using comics in the biology classroom has proven to be an effective strategy for improving students' reading comprehension and fluency (Jee & Anggoro, 2012).

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The success of science-themed *manga* (Japanese comics), *Cells at Work!* (2015-2021) and *Dr. Stone* (2017-now), are the first steps toward incorporating comics into the classroom (Inagaki & Boichi, 2017; Iwasaki, 2021; Septaria, 2022; Shimizu, 2015). However, because knowledge on this subject is not yet widely disseminated, comics as an art-based approach to conveying biology are still considered premature. As a result, a bibliometric analysis is required to map works on the Scopus database about how comics might be utilized to explain biology. To investigate the biology comics research, this paper aims to answer the following research questions:

1. What and who are the leading scientific journals that publish biology comics? What are the most frequently cited articles in biology comics research? Who are the most-quoted authors for research about comics in biology?
2. What are the most popular keywords used in biology comic research? How do keywords relate to each other?
3. What are the sample groups in comics in biology research?
4. What research methods are used in comic biology research?
5. Which areas of biology have been adapted into comics?
6. What types of comics are used to illustrate biology-related concepts?
7. What are distribution/implementation biology comics to readers?
8. What are the roles of comics in education?

Method

Articles Selection

On September 25, 2022, we searched the Scopus database for publications using the keywords “biology” and “comics” or “comic” or “graphic novel” or “visual narrative” and “biology” and “education” and “media” and “comic ” or “comics” or “graphic novel” or “visual narrative”. We also use specific keywords for each branch of biology such as “botany” and “comic”, “zoology” and “comic”, “health” and “comic”, “environment” and “comics”, “microbiology” and “comic” , and “evolution” AND “comics”.

The total number of items retrieved from the initial search is 501. Then, some of the articles were rejected since they were listed in the category of non-articles (editorial material, early access, and essay review). Each article's title, abstract, and keywords are manually evaluated to ensure they are written in English. Many articles were read, but only those that met two criteria—"the use of comics in teaching" and " the biological themes in comics"—were included in the final selection. In the end, only 66 articles were eligible for bibliometric analysis (Figure 1).

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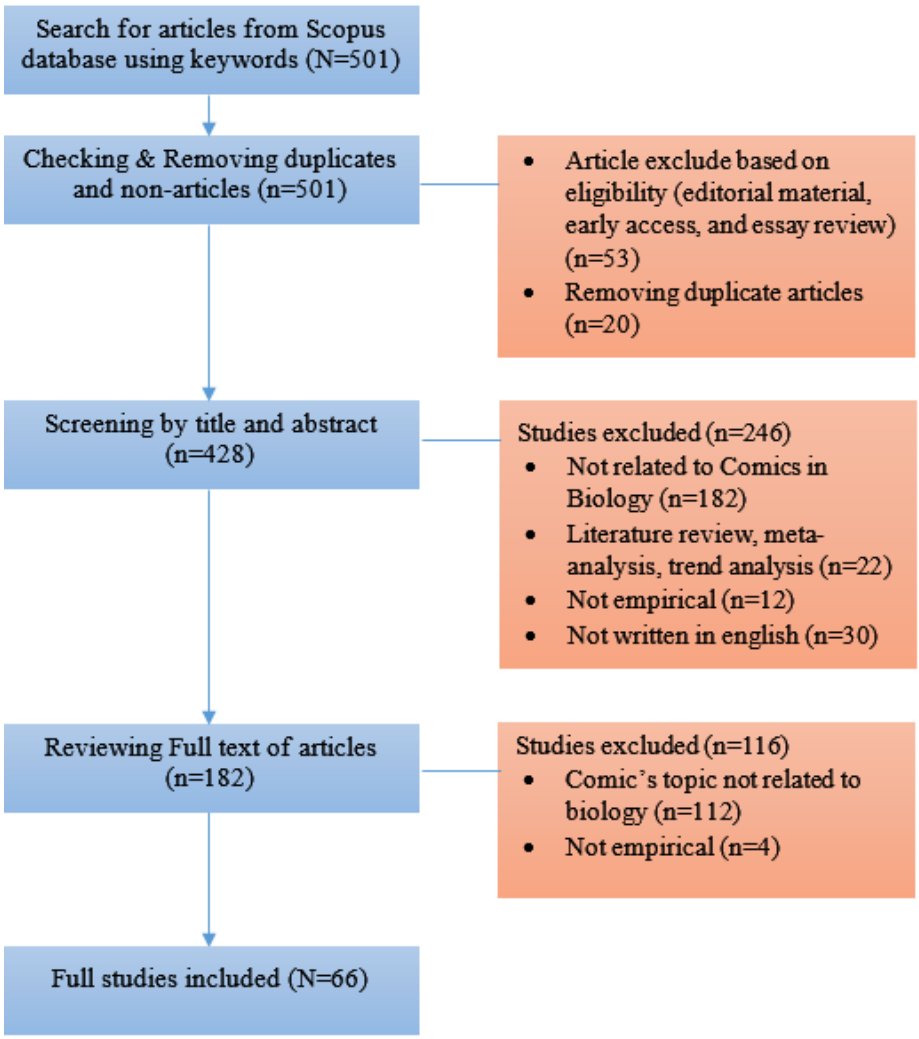

Figure 1. Article selection process

Data coding and Analysis based on criteria

The first two research questions were answered using bibliometric mapping analysis in VOSviewer. We used VOSviewer to examine citations, co-citations, and keywords in papers, and our analysis is presented as a visual representation.

To answer the following three research questions, we used the schema from the previous research. We evaluated comics from various perspectives from several dimension (Figure 2), research methodologies (Akcanca, 2020; Da Silva et al., 2017), sample groups (Şentürk & Şimşek, 2021), biology topics (Koutníková, 2017), comics types (Aggleton, 2019), comics implementation (Da Silva et al., 2017; Koutníková, 2017), and comics role (Şentürk & Şimşek, 2021).

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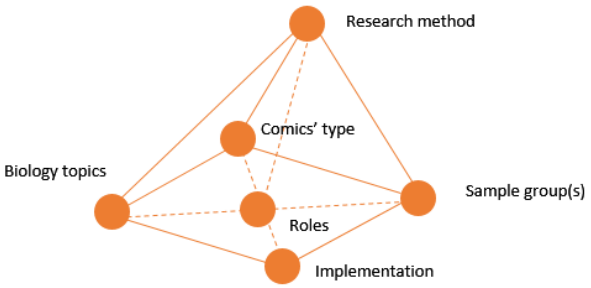

Figure 2. Dimension in comics biology

Data coding and Analysis based on the timeline

Figure 3 depicts the number of publications based on the selected articles, where 2011 is the oldest year. This number serves as the basis for our categorization and analysis. This coding method has been widely used by researchers in bibliometric mapping analysis (Hwang & Tu, 2021). We divided biology comics research into three time periods, grouped by four years, namely 2011-2014, 2015-2018, and 2019-2022. According to the results of our grouping, there were four research articles in the 2011-2014 group, twenty-three articles in the 2015-2018 group, and forty-nine articles in the 2019-2022 group. From Figure 3, it can be seen that research on biology comics has increased a lot in the last two periods.

Result and Discussion

Document Details

We categorized the top journals according to the number of documents and citations relevant to biology comics research. For each remaining criterion, we listed the top five journals. Table 1 depicts the journal's ranking based on the number of biology comics research articles. We did not rank the top five in this section since only four journals contain more than one article document connected to biology comics research. These are the AMA Journal of Ethics (4 documents), Comics Grid: Journal of Comic Scholarship, Journal of Visual Communication in Medicine, and Health Communication (two documents in each journal). The years covered by each article vary widely; for instance, the AMA Journal of Ethics has only published biology comics research articles from 2015–2018. The same is the case for Health Communication. In contrast, documents in Comics Grid: Journal of Comic Scholarship and Journal of Visual Communication in Medicine are distributed primarily from 2019 to 2022.

Contrary to the top journals with an enormous number of articles, the top journals with the highest citations are journals with only one biology comics-related article (except the Journal of Visual Communication in Medicine, which has a high number of citations). As a result, the top journals with the most

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citations are likewise tied to the top authors with the most citations. The contents of Table 2 are shown the five most-cited journals and the authors.

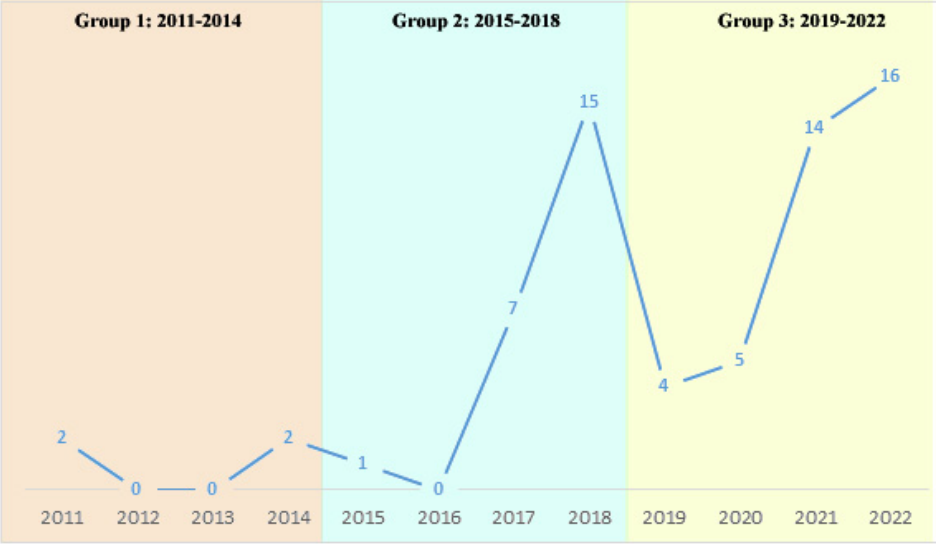

Figure 3. Groups based on timeline

Table 1. Top Journal by documents

Top Journals By Documents	Number of Documents		
	2011-2014	2015-2018	2019-2022
AMA Journal of Ethics	0	4	0
Comics Grid : Journal of Comic Scholarship	0	0	2
Journal of Visual Communication in Medicine	0	0	2
Health Communication	0	2	0

The first study, by Hosler and Boomer (2011), used pre-and post-tests to measure how non-major students feel about biology, how they feel about comics, and what they know about evolution. In their article, the authors also compare four biology courses. Moreover, the second study by Aisyah et al. (2017) is a media development study that examines socio-scientific concerns associated with the crude oil issue. After preliminary analysis and validation with experts, they made and tested the comics to see what students thought of them. The third study by Lin et al. (2015) investigated public perceptions of nanotechnology-related comics as a science communication medium. The fourth study by Kearn and Kearn (2020) focused on using comic books as a health communication media during COVID-19 pandemic. Furthermore, the latest study by Mandelson (2017)

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employed comics to improve disease-related information and treatment adherence in juvenile idiopathic arthritis patients.

Table 2. Top cited journals and authors

Journal	Article	Author(s), Year	Citation
CBE Life Science Education	Are comic books an effectiveway to engage nonmajors in learning and appreciating science?	Hosler J., & Boomer K.B. 2011	73
Journal of Physics: Confe-rence Series	Learning Crude Oil by Using Scientific Literacy Comics	Aisyah R. et al. 2017	41
International Journal of Science Education	Are Science Comics a Good Medium for Science Communication? The Case for Public Learning of Nanotechnology	Lin S.-F. et al. 2015	32
Journal of Visual Communication in Medicine	The role of comics in public health communication during the COVID-19 pandemic	Kearns, C., Kearns, N. 2020	27
Pediatric Rheumatology	Comics as an educational tool for children with juvenile idiopathic arthritis	Mendelson A. et al. 2017	16

These five articles are often cited as the basis for educational comics because they are about the main groups of topics in biology. For example, the first study focused on the main topic of general biology. The second research leads to the topic of environmental problems. Biotechnology is the focus of the third study. Lastly, the fourth and fifth research relates to health. This variety of topics is a good thing for comics as an educational medium, especially since the use of comics as an educational medium has been debated for a long time (Gruenberg, 1944; Hutchinson, 1949; Sones, 1944). Even the idea of science as a subject has only come about in the last 15 years (Jee & Anggoro, 2012; Tatalovic, 2009; Tribull, 2017).

Except for Kearns and Kearns (2020), all five authors who earned the most citations were published more than five years ago. It indicates that the effect of the publishing year increases with age. However, it is also important to note that the

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most significant number of citations is fewer than 100, showing that this type of research is still infrequently conducted.

After that, we used VOSviewer to create a visual representation of the citation analysis, allowing us to examine the interconnectedness of each journal. Based on the citation analysis results, we discovered a distinct cluster in biology comics research. Figure 4 demonstrates that the clustering comprises five colors (red, yellow, purple, green, and blue). On the other hand, the red cluster is very different from the other 4 clusters. It is because the research in the red cluster focuses primarily on general education concerning the incorporation of biology in the classroom. In contrast, the focus of the remaining four groups is on using particular comics in health education.

The circle size and networking pattern are determined by the number of documents, citations, and total link strength (the total strength of one journal's connections with other journals) (Van Eck & Waltman, 2017). The red cluster is dominated by CBE Life Science, the number one journal based on citations. In contrast, the AMA journal of ethics, the number-one journal based on the number of documents, dominates the remaining four groups. Figure 5 shows that CBE life science is related to journals like the Journal of Physics: Conference Series, the Journal of Microbiology and Biology, Ferns Microbiology Letters, and Urban Forestry & Urban Greening. On the other hand, the yellow, purple, blue, and green clusters have more complicated connections. The yellow cluster is led by epilepsy and behavior, the purple cluster by health communication, the green cluster by the AMA journal of ethics, and the blue cluster by the journal of visual communication in medicine (blue cluster).

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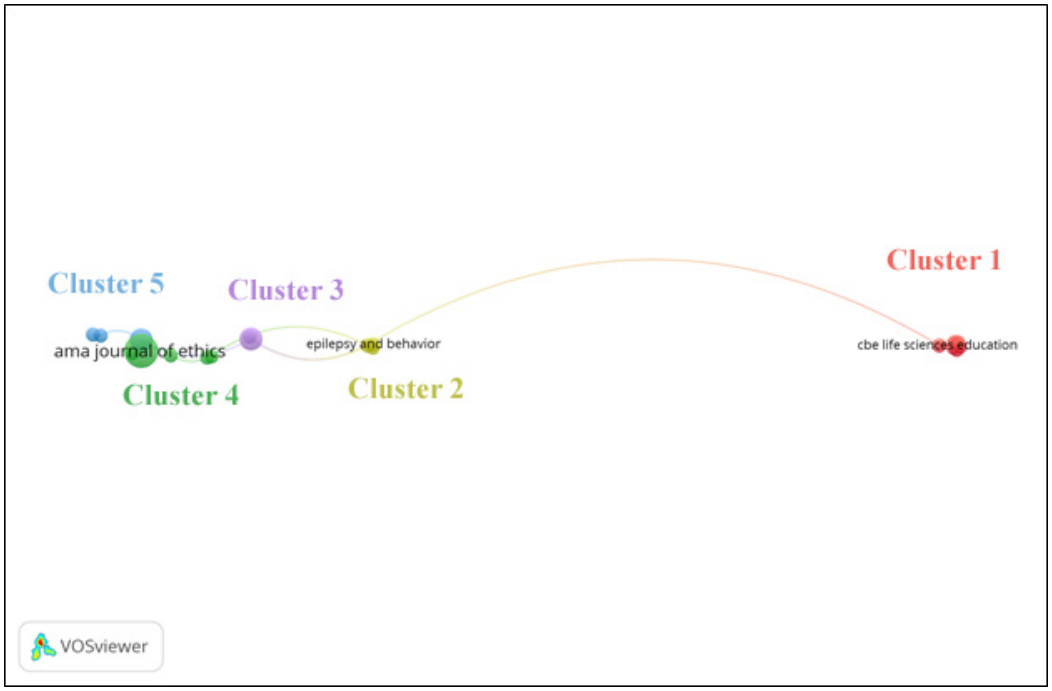

Figure 4. Interconnectedness of each journal

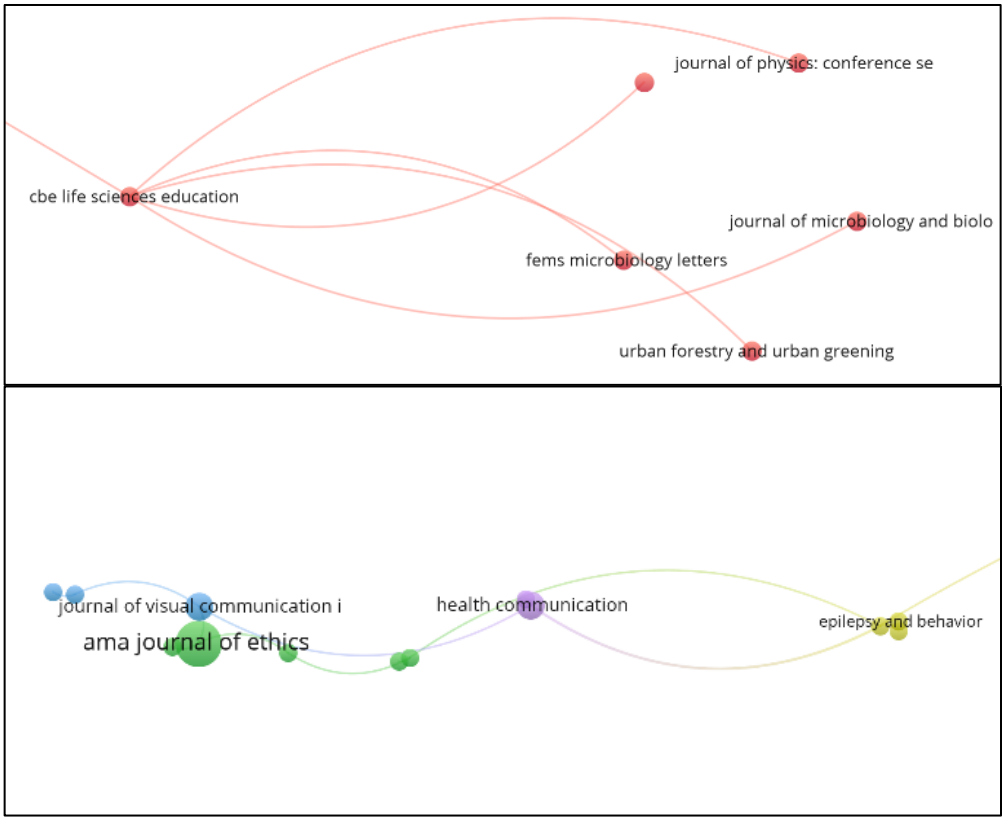

Figure 5. The detail of red, green, purple, and blue cluster journals

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Keywords

Based on author keywords, we discovered 212 keywords in 66 articles. The most frequently used keywords were comics (f=10), education (f=7), knowledge, health literacy, graphic medicine, and health promotion (each f=3). Figure 6 clearly shows that the keywords "comics" are the primary keywords in biology comics study. Based on data from VOSviewer's analysis, there are 16 keyword-based clusters. Here, however, we will focus on a subset of the most frequently used keywords.

The largest cluster is cluster 10, which contains the most frequently used keyword, "comics." Some of the scattered studies focus on using comics in formal education or health instruction. For instance, Cha et al. (2022) studied using comics in the classroom; their activity involved having students create comics about air pollution. Meanwhile, Ike and Anderson (2018) used comics to impart bioethics to students as part of their health education curriculum.

Cluster 13, with the keyword "education," is the second largest and is a more particular segment containing articles relating to the use of comics as learning media in the classroom. The research by Hosler and Boomer (2011), which we described earlier as a highly cited publication, relates to this cluster. They employ comics with an evolution theme to assess biology attitudes, comics attitudes, and evolution-related subject knowledge. Additionally, Pitura and Chmielarz's (2017) research utilized comics as a complementary medium. She/he implements a gamified extracurricular CLIL (Content and Language Integrated Learning) project.

Three-time-mentioned keywords (knowledge, health literacy, graphic medicine, and health promotion) build their clusters. These keywords stress using comics as a dissemination medium for health promotion and to increase health literacy. For example, Shimazaki et al. (2018) used manga to teach people with metabolic syndrome about exercise and healthy eating. In another study, Yu et al. (2017) compared how well pamphlets and educational comic books helped people with type II diabetes learn about their health. Their study showed that comics were better at helping people learn about their health.

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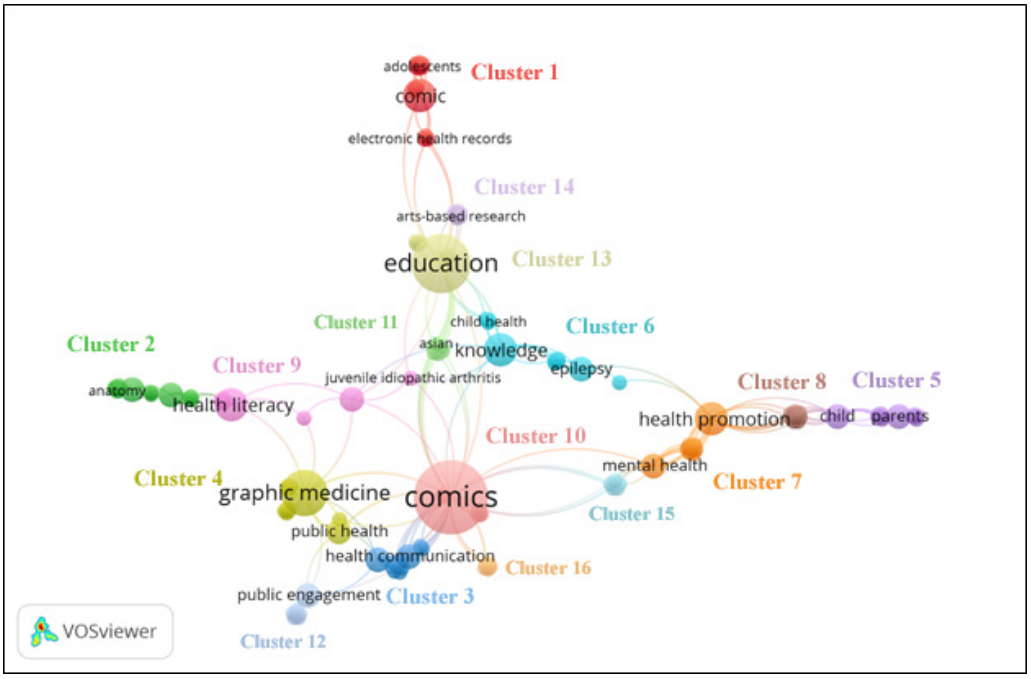
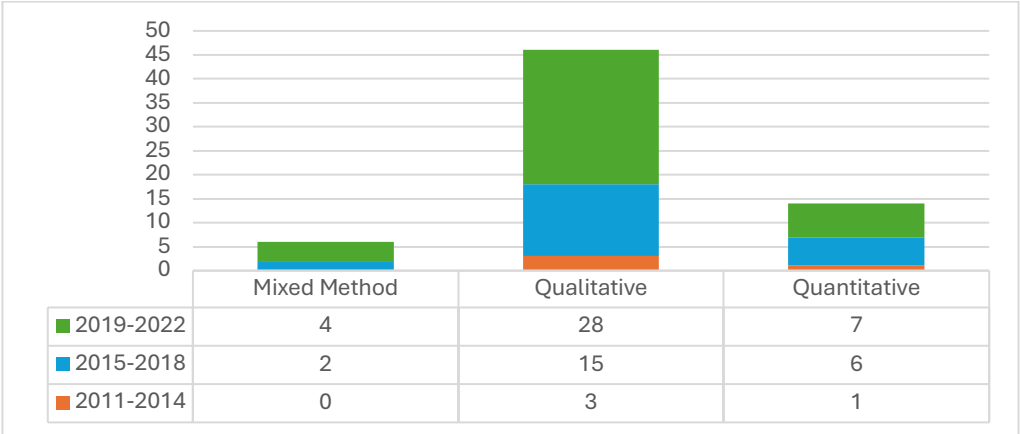


Figure 6. Keywords in biology comics research

Research Methods

Qualitative research is the most common approach in biological comics research, followed by quantitative and, at the very least, mixed-methods studies. Figure 7 shows that the different research methods for comics started in 2015. Before 2015, no one used mixed-method research.



	Mixed Method	Qualitative	Quantitative
2019-2022	4	28	7
2015-2018	2	15	6
2011-2014	0	3	1

Figure 7. Research method in each period

Research that examined the readers' perception (Kalra et al., 2022; Pitura & Chmielarz, 2017; Vipler et al., 2022; Whiting, 2020) or described comic design predominates as the most common qualitative approach in the field of biology comics (Alemany-Pagès et al., 2022). Quantitative research is typically dominated

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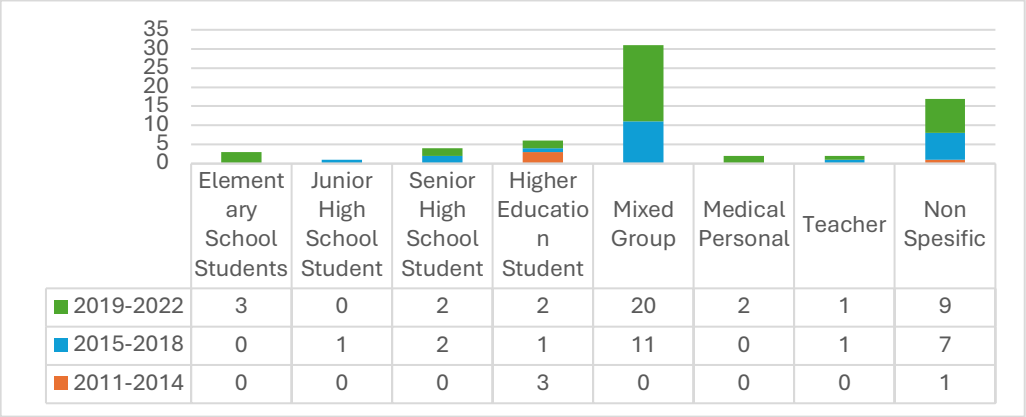
by survey research (Alkureishi et al., 2021; Muzumdar & Pantaleo, 2017), comparative quantitative (Hosler & Boomer, 2011), or experimental research (Lewis-Smith et al., 2022). Finally, mixed methods research, such as Willis et al. (2018), who generated motion comics as part of the intervention, used a qualitative and quantitative approach using the Sabido Methodology in generating their comics.



	Elementary School Students	Junior High School Student	Senior High School Student	Higher Education Student	Mixed Group	Medical Personal	Teacher	Non Spesific
2019-2022	3	0	2	2	20	2	1	9
2015-2018	0	1	2	1	11	0	1	7
2011-2014	0	0	0	3	0	0	0	1

Figure 8. Research samples of biology comics in each period

Research samples

Biology comics are used by various demographics, from elementary school students to non-specifics, as research samples (Figure 8). We define a few terms before explaining this part. A *mixed group* is a target group that includes high school, college, and adult readers. So, a *mixed group* means that the comics are for different groups. There are also comics for specific professions, such as teachers and medical professionals. For *non-specific*, the sample of comics is the general community.

As can be seen from the distribution of comics, most targets are mixed groups and non-specific groups. Some researchers in comic biology choose a broader scope for applying comics in specific investigations. For example, Surbhi & Anand's (2019) study used comics to teach women of various ages about menstrual hygiene management. Also, comics tend to have broad audiences, as seen in studies like Kearn & Kearn's (2020) study, which created digital comics on COVID-19 to serve as public health communication.

Biology Topics

Figure 9 shows that comic biology covers a wide range of topics. In the first group, we put the topics into four main groups: biotechnology, environmental issues, general biology, and health. Based on these main topics, we break them

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down into subtopics. Figure 9 shows that the topic is dominated by health, which comprises ten subtopics. This topic comes up in all three groups of timelines. Other topics, except for general biology, only showed up in the range of 2015 to 2019. If we look at the sub-topics, we can see that some of the subtopics in general biology have the exact subtopics with health (for example, microbiology and anatomy); the difference is the direction of the topics. Microbiology focusing on health is primarily concerned with microbiology in the health sector. In contrast, microbiology in general biology focuses on explaining microbiology in general.

Like many studies we discussed earlier, health has been a big part of the biology comics in the last few decades. Three health-related journals dominate the list of highest-cited publications, supporting this finding. In truth, only a single art journal covers biology comics. Noe and Levin (2020) also support the finding that they discovered at least 941 articles on Scopus and 903 on the Web of Science using the keyword "Graphic medicine" concerning comics. These findings represent that biology-related comics are still highly specialized in health, and other researchers can use these findings to raise topics outside the scope of health.

Comics types

Comic books make up most of the comic type as a whole. Over fifty percent of the conducted studies utilize comic books (Figure 10). The form is dominated by printed comics, with only a tiny portion available digitally. Before elaborating on this part, we will define words for comic types. A comic book is a book-shaped comic with multiple pages and many panels. Typically, this comic type consists of an entire tale or a collection of comic strips (Aggleton, 2019). The comic strip is less complex than comic books since it has one or a few panels with a small number of panels (Aggleton, 2019). Comic motion is a type of comic with moving elements that are short films or gif images (typically in digital form) (Aggleton, 2019).

We assess that because the objective of comics includes the diffusion of information, such as health education, it is necessary to have comics with a significant number of pages because there is also a great deal of information transmitted. As a result, many academics choose comic books over comic strips or motion comics, which consist of only a few panels. Even though there is no research on the effectiveness of different types of comics, some researchers think that comic books with more pages can give complete information than comic strips (Romero-jódar, 2013; Tiemensma, 2009)

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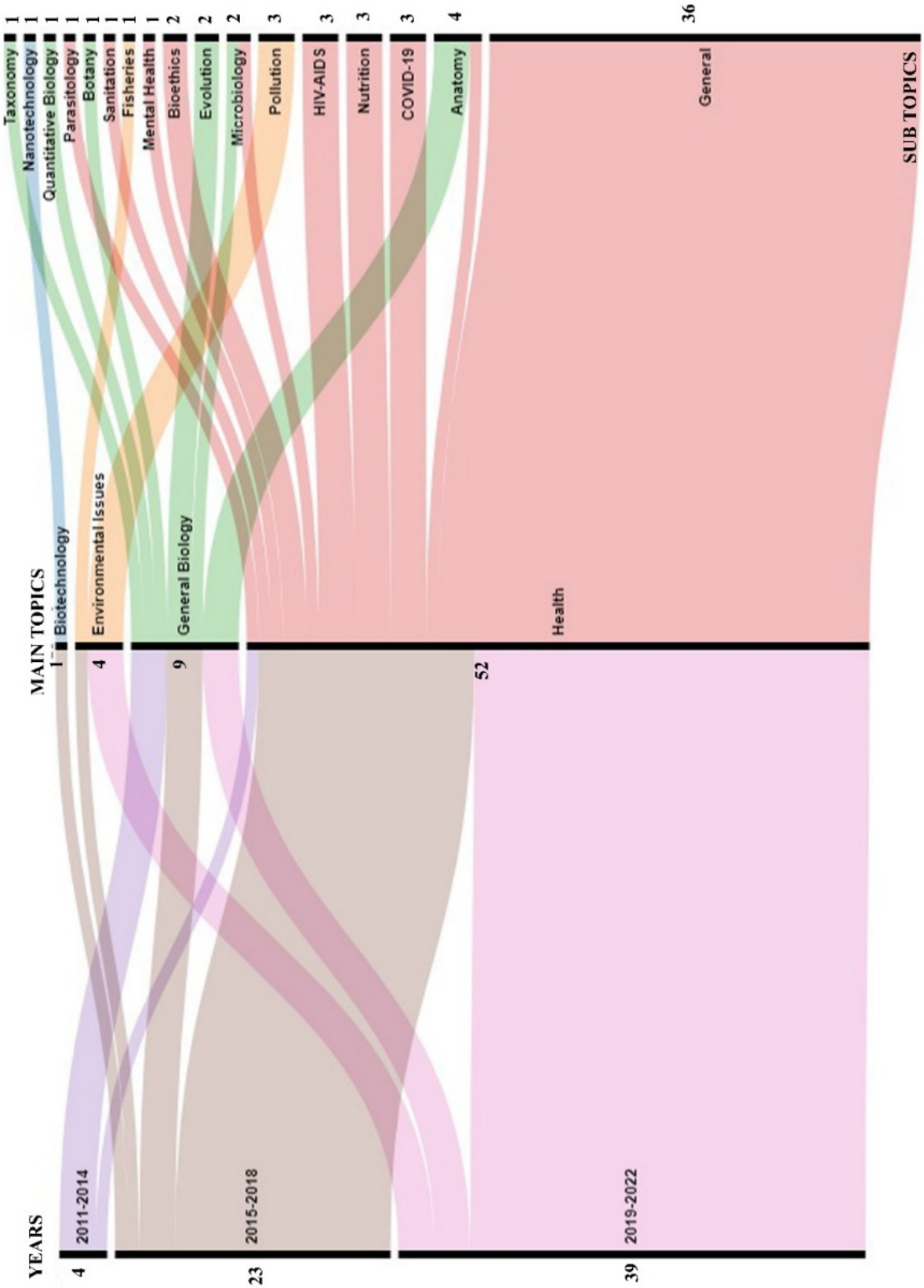

Figure 9. Topics in comics biology in each period

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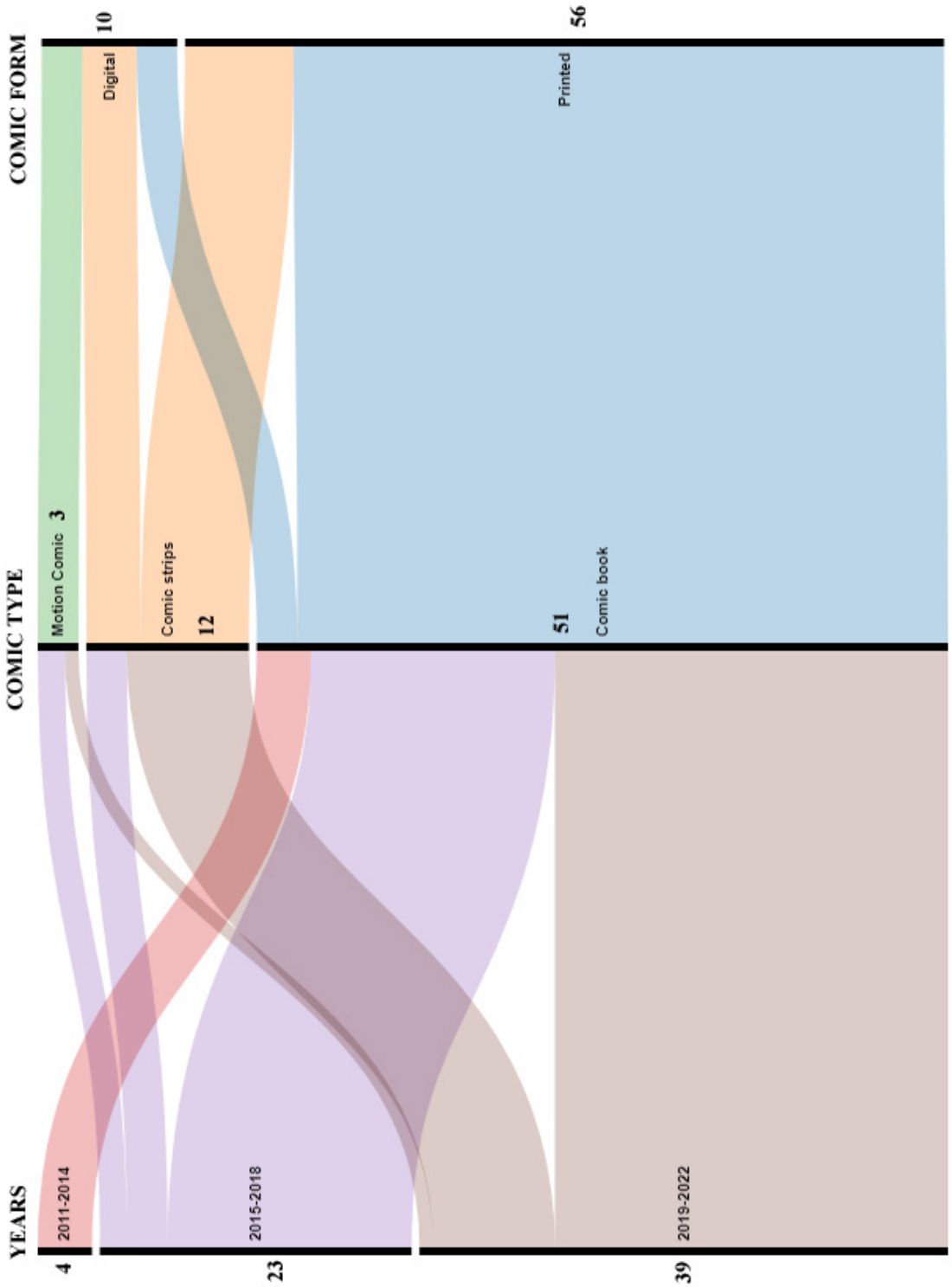

Figure 10. Comics types in each period

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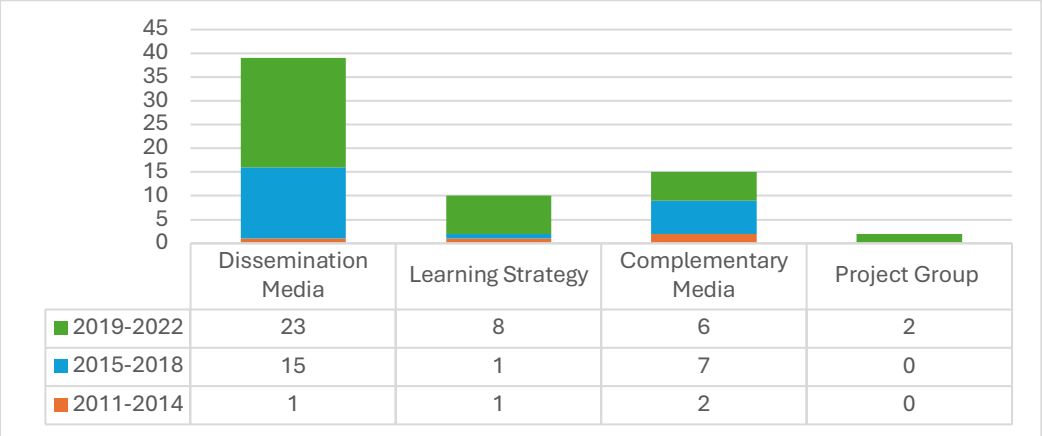
Implementation of comics

We classified the implementation of comics for readers following Koutníková (2017) and Da Silva (2017). Comics are implemented in four categories: dissemination media, learning strategy, complementary media, and project groups (Figure 11). Most of the research used comics for dissemination media from 2011-now. Numerous studies that use comics to transmit information demonstrate the significance of comics as a dissemination medium (Hands et al., 2018; Lin et al., 2015). In addition, comics, as the core component of the learning process, represent comics as a learning strategy (Hosler & Boomer, 2011; Vipler et al., 2022; Whiting, 2020). Comics as complementary media mean comics as additional media in a variety of learning materials, such as Morel (2019), which included microbiology comics as one of the learning resources. Thomas et al. (2021) project to develop fish ecology comic books exemplifies the comics as a project group.



	Dissemination Media	Learning Strategy	Complementary Media	Project Group
2019-2022	23	8	6	2
2015-2018	15	1	7	0
2011-2014	1	1	2	0

Figure 11. The implementation of biology comics in each period

Comics Roles

Roles from comics refer to Şentürk and Şimşek (2021), divided into a contribution to individuals, contribution to learning, and solutions for learning difficulties (Figure 14). Individual contributions have only the objective of enhancing personal knowledge. Contributions for learning focus on comics' role in assisting or reinforcing a learning process. Lastly, the solution for learning difficulties is the same as the contribution to learning. However, this role occurs due to classroom issues, as opposed to the contribution to learning, which is an initiation plan for integrating comics into the classroom.

The Figure 14 clearly shows that the contribution individuals dominate the three timeline groups. Interestingly, comics' roles began to diverge between 2019

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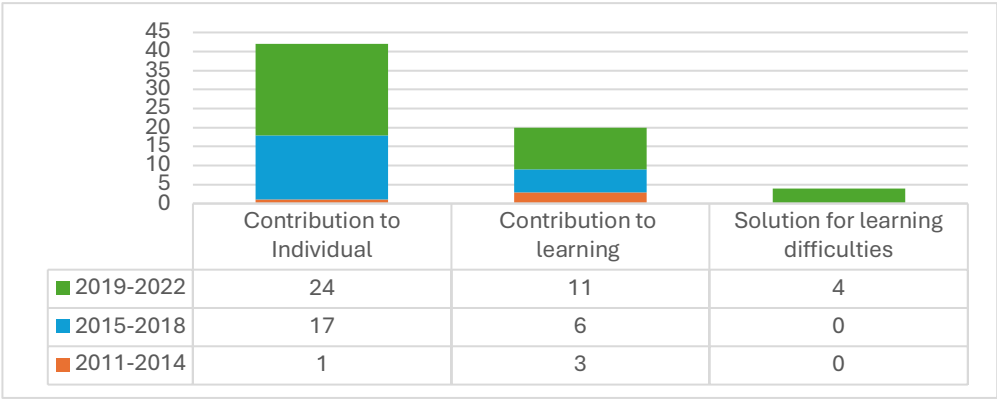
and 2022, as three roles appeared equally in that period. As indicated in the studies in the implementation part, the implementation of comics, which is dominant as a dissemination tool, is more tied to the contribution to individuals (Hands et al., 2018; Lin et al., 2015). Contributions to learning are primarily associated with using comics as a learning tool in the classroom or as a collaborative endeavour between teachers and students (Hosler & Boomer, 2011; Thomas et al., 2021; Vipler et al., 2022; Whiting, 2020). Meanwhile, the solution to learning difficulties frequently begins with a problem, such as the research of Cicero et al. (2020), which arises from the problem of high school students' stigma of people with epilepsy, particularly among high school students. According to their study findings, using comics improves knowledge, attitudes, and behaviours around the disease.



	Contribution to Individual	Contribution to learning	Solution for learning difficulties
2019-2022	24	11	4
2015-2018	17	6	0
2011-2014	1	3	0

Figure 12. Roles of comics in each period

Reflection and potential future research in biology comics

Based on the results of the bibliometric mapping and the distribution of research based on three timeline groupings, it can be inferred that there are several areas for future research. In this section, we will discuss the reflections and potential future studies in the field of biology comics.

In terms of research methodology, qualitative and quantitative approaches predominate. Integrating the two approaches offers up possibilities for mixed methods study. We believe that utilizing a mixed method will yield more complete findings than using simply one type of approach. Some example frequently occurs in art-based research on subjects other than biology. For instance, Leonard and Odutola (2016) employed questionnaires (quantitative part) and student portfolios (qualitative part) to evaluate how students' perceptions during an art course. These two methods provide a complete picture of students' perceptions in quantitative and qualitative data analysis.

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As evidenced by the sample research data, comics are primarily intended for diverse audiences and lack specificity. Comics have unique characteristics for different readers since young readers may not necessarily enjoy comics with the severe theme for adults. Even mainstream comics and manga have age restrictions (Serantes, 2014). As a result, there is a chance in the future to create comics that are segmented for school-aged children, particularly those in elementary school and junior high school, as comics remain uncommon among readers of these ages.

For the topics of biology comics, which are dominated by comics about health, there is a huge possibility to make comics with a different focus. Multiple prominent themes, such as environmental issues within socioscientific issues, might be brought up, given the abundance of research in this area (Abrori et al., 2020; Evagorou, 2011; Herman et al., 2018). Given the tremendous growth of biology education over the past decade, biotechnology is also one of the prospective themes that might be addressed in biology education (Goh & Sze, 2019; Riandi et al., 2022). Even specific scientific disciplines that have not yet been explored in comics, such as zoology, ethnobiology, morphology, genetics, and biochemistry, have considerable potential for future development.

Researchers may need to change how they study comics in the future. Strip and motion comics are suitable for the digital era since they are more shareable than multi-page comic books (Maity, 2022; Wang & Liu, 2021; Wershler & Sinervo, 2021). Even some digital platforms, such as Instagram and Youtube, are excellent for sharing comic strips with small file sizes, or motion comics are more attractive due to the presence of movement (Andersen & Vistisen, 2020; Annisa et al., 2021).

From implementation data, it is also necessary to consider comics as either the primary media for dissemination or supplementary media. Future research could focus on comics as a learning strategy or group project. Aside from biology, comics as art-approach learning has numerous positive effects on the learning process (Priatin et al., 2021; Zamora et al., 2021). As a project group, numerous comics have been developed (Jonsson & Grafström, 2021; Rosalin & Ying, 2021), and there are great opportunities to develop scientific comics that contain dense but easy-to-understand biological content for readers through the collaboration of diverse experts or students.

For the comics role data, comics could be seen more as a way to help people learn, especially when it comes to literacy or getting better at reasoning and critical thinking, instead of just helping individuals. Comics have the potential to improve literacy-related issues, which will ultimately result in students' reasoning and critical thinking (McVicker, 2018; Putri & Fida, 2018). There are numerous opportunities to optimize the roles of comics in the completion of

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learning solutions, such as incorporating them into action research or design-based learning.

Conclusion

To summarize, this paper uses bibliometric analysis to describe trends in research related to the use of comics in the context of biology. Unfortunately, research on this topic is limited and segmented. Based on the findings and discussions, we provide a detailed description of what we discovered, our reflections and the possibility of future research in this area.

This investigation still has limitations. For instance, we only utilize a SCOPUS database, which may only be capable of listing SCOPUS-indexed articles. Future research may be able to expand the database for similar research by using databases from Web of Science, ERIC, or Google Scholar. Another limitation is that the articles we analyze only use English articles; this allows other researchers to investigate non-English articles related to research trends in biology comics.

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