REVIEW ARTICLE

Flipped classroom strategies in biology learning: A systematic literature review

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Abstract: Biology as an integral part of science learning continues to be maximized by integrating technology into its learning design. The definite manifestation of this integration process is to achieve meaningfulness, activeness, and effectiveness of the learning carried out. The flipped classroom (FC) is gaining popularity as a pedagogical model that uses the important benefits of technology in its learning environment. FC is proven to be an effective teaching mode that empowers students' 21st-century skills, stimulates students' self-learning, and improves academic performance. The potential of the FC is interesting to explore to what extent biology welcomes the FC. The aimed of this systematic literature review is to review and analyze articles published by Scopus indexed journals. We used the keywords "Flipped classroom and biology" in the search menu in the Scopus database and succeeded in finding 72 articles. There were 21 articles that met the criteria for further analysis. The inclusion and exclusion model used is PRISMA. The findings obtained are the trend of FC publications in biology learning over the last ten years. The approaches used in this research include quantitative, mixed method, case study and qualitative. Key words that are often used by writers are student, human, biology. The biology keyword has a branch, namely active learning. There are 9 countries of origin of authors who publish articles. The United States is a country that is active in publishing. Articles published on each continent are not evenly distributed. The dominant articles are published in collaboration with one country and rarely are articles published by one author. We have succeeded in formulating a picture of the existence of the FC in biology learning over the last ten years. These findings can be a consideration or reference for researchers to explore and study more deeply research related to the FC in biology learning based on their respective urgency.

Keywords: biology; flipped classroom; online learning; Scopus database; systematic literature review

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Introduction

The rapid development of technology and information has brought major changes to all aspects of people's lives, including the emergence of new opportunities to change teaching modes in various educational institutions (Salas-Rueda, 2023; Xie et al., 2022). This learning transformation leads teachers to create flexible spaces that allow students to choose when and where they learn by involving digital devices (Noguera Fructuoso et al., 2023). One effective strategy for maximizing the potential of active learning in the classroom and providing individualized support to students is the flipped classroom (FC) (Barral et al., 2018; Isabel Santos & Serpa, 2020; Kim & Jeong, 2017).

Flipped classroom (FC) is a pedagogical approach that reverses the traditional teaching structure to achieve meaningfulness, activeness, and effectiveness of learning by reversing the traditional teaching structure and shifting the learning orientation from the teacher to the students (Cevikbas & Kaiser, 2022; Oppong et al., 2022). Candel et al. (2023) view FC as a way of learning that is different from traditional learning, because students gain new knowledge not only in class but also have the opportunity to

construct knowledge in other spaces such as at home through the use of technology. The FC describes a learning environment that introduces key concepts from a particular topic online (by providing instructional videos, reading materials, multimedia teaching materials or a Learning Management System (LMS) and spending face-to-face time in class with activities that are activate students, such as solving problems, assimilation of knowledge, explaining difficult concepts, and discussion

The FC provides the opportunity for a flexible teaching and learning process (Collado-Valero et al., 2021; Stöhr et al., 2020). As a result, FC has become a popular teaching strategy for delivering material content, including science learning (Doğan et al., 2023; Windmuller-Campione & Carter, 2017). This is because FC facilitates students in learning by doing so that they have the opportunity to develop themselves by building their own knowledge (Aydin & Demirer, 2022). The implementation of FC also encourages students' independent learning and determines their respective learning rhythms using online learning platforms (Aljaber et al., 2023; Sun et al., 2023).

Based on the meta-analysis obtained, students' perceptions regarding FC are generally positive (Chen et al., 2017). The FC widely discussed as an instructional approach that contributes to improving learning outcomes (Loveys & Riggs, 2019; Meyliana et al., 2022; Ridlo et al., 2022). The FC has also been proven to have a positive impact on student learning achievement (Murillo-Zamorano et al., 2019; Strelan et al., 2020; Van Alten et al., 2019). The application of FC in learning is known to improve students' cognitive abilities such as critical thinking (Styers et al., 2018; Sugrah et al., 2023), creative thinking (Rahayu et al., 2022), and problem-solving skills (Yu et al., 2023). Other research also shows that FC can develop other skills such as collaboration (W.-Y. Hwang et al., 2023; Love et al., 2014) dan self-regulated learning (Du et al., 2023; Sletten, 2017). Additionally, certain studies confirm that FC can empower literacy in students such as science literacy (Cheng et al., 2023) and digital literacy (Riyadi et al., 2021). This is what makes FC need to be applied in various learning areas, including biology.

Based on searches conducted in the Scopus Database, it was found that there were paper related to systematic literature review (SLR) that discussed FC. Such as the use of FC in mathematics learning (Cevikbas & Kaiser, 2023; Fornons & Palau, 2021; Fung et al., 2021), science learning in elementary school (Purnama et al., 2023), EFL course (Linling & Abdullah, 2023; Zain, 2022), Higher education in general (Baig & Yadegaridehkordi, 2023; Divjak et al., 2022), programming course (Hendrik & Hamzah, 2021), business and entrepreneurship education (Senali et al., 2022), gamification (Ekici, 2021), and self-regulated learning in FC (Rasheed et al., 2020). However, none of these found the extent of FC's relationship with biology learning.

Biology as part of modern science learning aims to develop scientific thinking skills to be applied in everyday life (Agudo-Ruiz, 2022; Ahuja, 2021). To achieve this level of modernity, biology learning in the 21st century needs to be maximized by integrating technology in learning design (Molina et al., 2023). Due to the potential that FC has, it is interesting to explore the extent to which biology welcomes the FC. In this regard, based on search results on the world's largest reputable database, namely Scopus, it is necessary to carry out a comprehensive study regarding FC research in biology learning. These publications need to be analyzed to find important information regarding the existence of FC in biology learning from various categories. One of the recommended techniques for studying and analyzing is to carry out a systematic literature review (SLR). Categories that need to be analyzed are year of distribution, type/method of research, author and keywords, author's country of origin, international collaboration and connection to the Covid-19 pandemic (Cevikbas & Kaiser, 2023; Husamah et al., 2022b, 2023)

Therefore, this SLR aims to analyze research trends related to the FC in the biology discipline. The SLR provides a number of advantages for researchers, especially in presenting a classy and comprehensive overview of the literature contained in databases that are interesting to research. The SLR also helps researchers identify research gaps, both methodologically and research challenges that require further investigation. The SLR is also a space for researchers to develop new research ideas and synthesize various references critically and constructively to obtain more effective information (Peričić & Tanveer, 2019). Efforts to study the trend of the FC in the biology discipline are important because it can become an information map that shows the current position of the FC in biology learning. The trend of the use of flipped classrooms in biology learning is the basis for the author in conducting research on the development of constructivistic learning models combined with blended learning such as flipped classrooms.

Method

Study type

This study includes a Systematic Literature Review (SLR), is a valid, reliable and repeatable technique (Xiao & Watson, 2019). The SLR is a way to identify, evaluate and analyze various information contained in the literature critically to answer research questions and analyze them in depth (Liberati, 2009; Snyder, 2019). SLR helps in creating a summary of current knowledge related to research questions using

systematic and transparent methods (Husamah et al., 2022a; Kurniati et al., 2022).

Research questions (RQ)

The formulation of research questions is used to determine the scope so that there is a clear focus regarding the research. Research questions were developed in response to the needs of the selected topic, namely:

RQ1: What is the trend of publications related to FC in biology learning in Scopus indexed journals?

RQ2: What is the description of the existence of FC in current biology learning?

Trend limitations focus on: distribution of articles by year, trending keywords, author's country of origin, collaboration in publication, type of research, branch of biological science discipline, and academic level of FC implementation.

Search article and inclusion criteria

Researchers used the keyword "FC" in the SCOPUS database search menu. The data obtained was stored in *CSV and *RIS form which was then connected to the Reference Manager (Mendeley). VOS-viewer software is used to visualize data to make it clearer, more interesting and communicative. As for our search history on SCOPUS, that is “TITLE (flipped classroom) THEN (flipped classroom +biology) AND (LIMIT-TO (PUBYEAR, 2023) ATAU LIMIT-TO (PUBYEAR, 2014) AND (LIMIT-TO DOCTYPE, “ar”)) AND (LIMIT-TO PUBSTAGE, “final”)) AND (LIMIT-TO LANGUAGE, “ENGLISH”)) AND (LIMIT-TO (SUBJAREA, “SOCI”)). We found 33 articles that used these terms and search patterns. We used preferred reporting items for systematic reviews and meta-analysis (PRISMA) to perform inclusion and exclusion. This PRISMA refers to (Gallagher et al., 2016) which is also used by (Husamah et al., 2022a)

The inclusion criteria used consist of four points. First, researchers only took articles published during the last ten years starting from January 2014 to December 2023. Second, articles included original research/articles. Third, researchers decided to take articles published in English. Fourth, the article is related to the field of social science.

The order of inclusion and exclusion carried out in this systematic literature review (SLR) is presented in Figure 1.

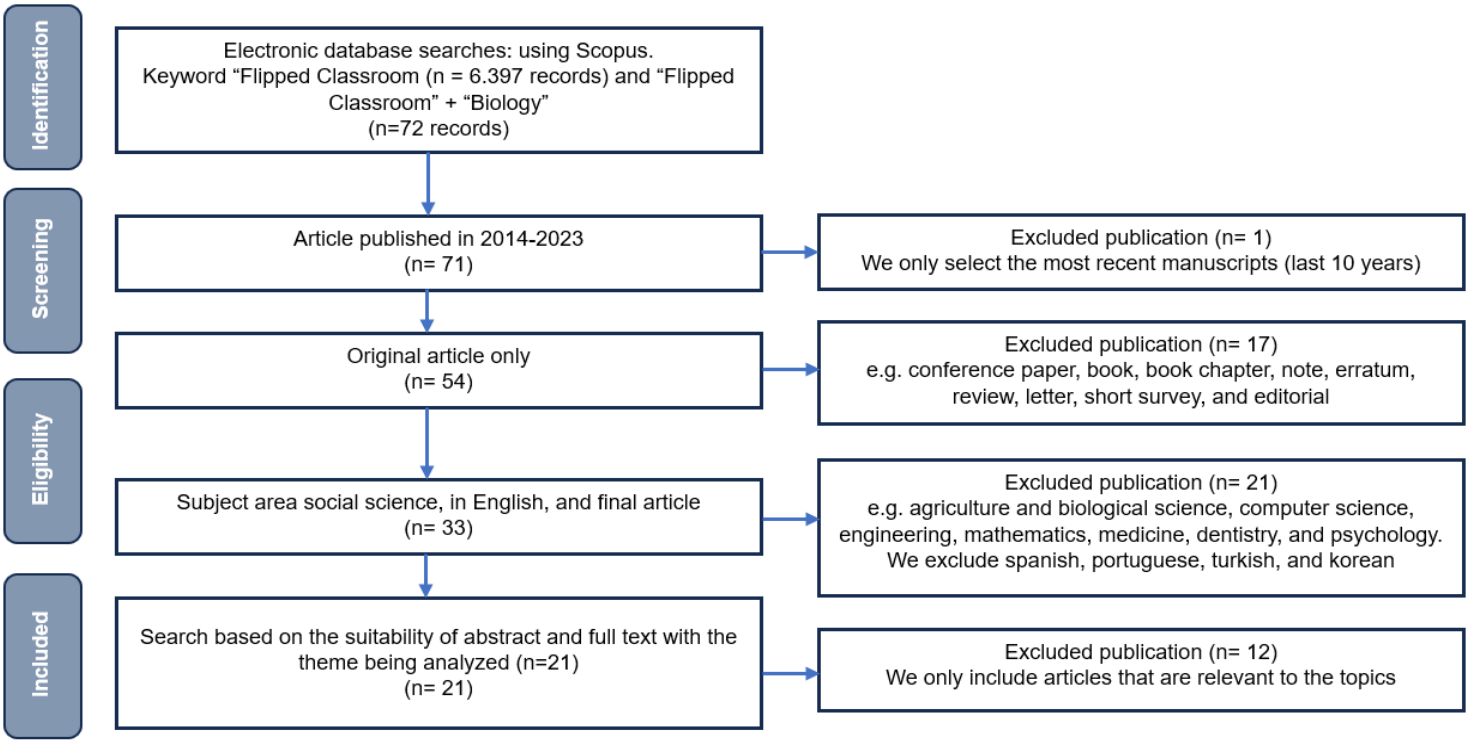

Figure 1. Systematic review flow diagram using the PRISMA model (Source: Results of researcher elaboration)

Based on Figure 1, it is illustrated that in the initial search the author found 6,397 articles using the keyword " flipped classroom ". However, because this SLR focuses on analyzing FCs in biology learning, the author added keywords and found 72 articles, resulting in 6,325 exceptions. Then, the author only took articles published in 2014-2023. This is because writings in the last 10 years contain the latest

information and are more developed than previous research. There were 71 articles that met these criteria, so only 1 article was excluded. Next, the author used the original article criteria, the result was 54 articles, so 17 articles were excluded. The author further provided criteria by determining to only select articles that were in English and found 48 articles. Thus, there were 6 articles that experienced exceptions. Furthermore, the author used the inclusion criteria in the field of social science in English to produce 33 articles that met the criteria, meaning that there were 15 articles that were eliminated by the author. The author rejects articles that do not match the theme to be studied, such as agriculture and biological science, computer science, engineering, mathematics, medicine, dentistry and psychology. The author also makes exceptions for languages such as Spanish, Portuguese, Turkish and Korean to prevent misinterpretation.

As writers who were directly involved in preparing this SLR, we feel that we do not have the ability to understand these languages optimally. We decided not to use Google Translate, which is a digital translator that is widely used by many people to avoid translation errors and misinterpretations and would require a lot of money if we involved professional translation services. In the final stage, the author re-examines the existing articles, ensures the suitability of the article to the theme to be elaborated, and uses English as a bridge of communication to the most universal readers. Based on this, the author obtained 21 articles that met the specified criteria. This means that there were 12 articles that did not meet the criteria and were excluded.

Results and Discussion

Flipped Classroom Publication Trends in Biology Learning

Year distribution

The distribution of years becomes an important aspect for reviewing FC research trends in biology learning. The distribution of years provides a comprehensive understanding of the development of research topics over time. Through analysis of the distribution of publication years, researchers can identify trends, changes and research focuses. The Figure 2 show FC research trends in biology learning from 2014-2023.

Figure 2. Distribution of article years (Source: Results of researcher elaboration)

Figure 2 shows the number of articles published from 2014 to 2023. Based on Figure 2, it can be seen that the number of publications regarding the FC in biology learning has fluctuated. There is unique data where in 2018 and 2020 the number of articles published was the same. Apart from that, there was a decrease in article publications from 2022 to 2023 and only 1 article was found that discussed the FC in biology learning. Publications related to this theme will probably not increase considering that the search for this data was carried out at the end of December 2023. One week into 2024, so the number of articles will stagnate in the Scopus database and it is possible that they will only be found in 2024. So, it can be said that research related to FCs in biology learning is of little interest to researchers.

There were 21 articles selected and analyzed in this systematic literature review. Articles were published in the period 2014 to 2023 (although in certain years no articles related to the formulated theme were found). As shown in Figure 2, the number of articles published fluctuates or tends to vary from year to year. Turan (2023) stated that 2015 was the year there was an increase in the amount of research related to the FC in science learning. However, this claim is not entirely directed at the field of biology as part of

science. Researchers only found 1 article published in 2015. 2018 and 2020 were the years when the most articles were produced regarding the FC in biology learning. Torres Martín et al. (2021) noted that research related to the FC during the Covid-19 pandemic has increased. However, this also does not represent the application of the FC in biology learning during the pandemic. Researchers found that of the 5 articles published in 2020, all did not discuss the application of the FC during the pandemic. Future researchers should see this as an opportunity to further develop the implementation of the FC in difficult times that can occur at any time. The existence of FC research innovations in biology learning that are continuous in nature will support the emergence of new research. This is in line with the opinion of Divjak et al. (2022) which states that more innovative research is needed regarding different ways of delivering material from FC learning in any field of science.

The lack of research related to FCs in biology learning has received less attention than FC research in general could also be caused by the tendency of researchers to assume that other topics are more urgent or popular in educational scientific literature. The growth of a research topic is thought to be a form of hype from the many previous publications related to that topic, so that by conducting research related to this matter, many authors will refer to the published articles (Klavans & Boyack, 2017; Sjögårde & Didegah, 2022). However, it cannot be denied that the decision to prioritize research regarding the FC in biology learning could result in a lack of understanding of the innovative potential of this theme.

Type/Research Method

Grouping of research types has a key role in SLR. The grouping fostered a deeper understanding of the diversity of methodologies used in FC research. The author can identify methodological tendencies, strengths, weaknesses in the existing literature. Table 1 is displayed that contains the types of research on FC topics in biology learning.

Table 1. Types of research on the FC theme in biology learning

No	Types of research	n	References
1	Quantitative	13	Vries (2023), Jensen et al. (2022), Ristanto et al. (2022), Waddell et al. (2021), Ebrahim et al. (2021), Bassett et al (2020), Tan et al. (2020), Goff et al. (2018), Jensen et al. (2018), Styers et al. (2018), Barral et al (2018), Županec et al. (2018), Jensen et al. (2015),
2	Mixed Method	5	Haagsman et al. (2020), Eichelberger et al. (2020), Awidi et al. (2019), Loveys et al. (2019), Sletten (2017)
3	Case study	2	Lashley & McCleery (2020), Gariou-Papalexiou et al. (2017)
4	Qualitative	1	Ridlo et al. (2022)

The types of research that are generally used regarding the theme "FC and biology" are presented in Table 1. FC research predominantly uses a quantitative approach (13 articles). Mixed method research is also quite large, this can be seen from the discovery of five articles that used mixed method research. This indicates that research related to the FC is not only sufficient to be approached using a quantitative approach but needs to be strengthened with a qualitative approach and data. Then researchers also have an interest in using case studies (2 articles). However, there is a gap where there is only 1 article that examines the FC using only a qualitative approach.

Much research related to "FCs and biology" is carried out using a quantitative approach. This is normal because the quantitative approach allows researchers to see the continuity of the "effect of treatment" which is measured objectively by looking at patterns and significant statistical relationships between the variables studied, so that strong empirical evidence can be produced (Leedy & Ormrod, 2015). Quantitative approaches also provide a strong basis for researchers to make generalizations to larger populations (Mat Roni et al., 2020). This finding is slightly different with Jou and Martin (2021) which actually reported that mixed method research was the dominant type of research used in the application of the FC in mathematics learning. The research theme regarding the FC in biology learning can actually be reviewed from the perspective of quantitative data or qualitative data or combining the strengths of both, which is known as mixed method research. The mixed method approach is a type of research that is quite popular in various fields (Ilgaz, 2023; Ivan et al., 2023; Roehling et al., 2017). Yarım et al. (2023) considers that the use of mixed methods is very appropriate as an effort to obtain information from various dimensions and explain the complexity of using the FC in biology learning in a comprehensive manner. To strengthen the interpretation of research data and produce more effective hypothesis tests, researchers need to use a mixed method approach to review FC science learning, including biology (Schultz et al., 2014).

There are 2 articles that use a case study approach. This indicates that the FC is further explored using more different methods. Case studies can be used in various scientific disciplines, including biology learning. Teachers try to direct students to apply the concepts they learn in real life with cases that have

sharp divergences (Lukitasari et al., 2020).
The unique information found was that only 1 article was found that used a qualitative approach. The lack of a qualitative approach used in this theme is predicted because of the tendency of researchers to combine quantitative data and qualitative data obtained in order to produce valid and credible findings. This can be an important signal for future researchers so that they can develop FC research on biology learning using a qualitative approach. Meriam and Tisdell (2015) explains that qualitative research has great potential in enriching contextual understanding of a phenomenon and allows researchers to explore in detail various things that are overlooked in quantitative research. In particular, efforts to increase the quantity of qualitative research provide benefits because they provide a way for researchers to obtain data from subjects as a whole on this theme (Ridlo et al., 2022). Thus, the use of a qualitative approach must continue to be studied in the application of the FC in biology learning.

Keywords

Figure 3 shows the trend of keywords generally used by authors in writing the theme "FC and biology". Based on Figure 3, it shows that there are three main keywords (biology, human, and student) that appear most often and are related to each other.

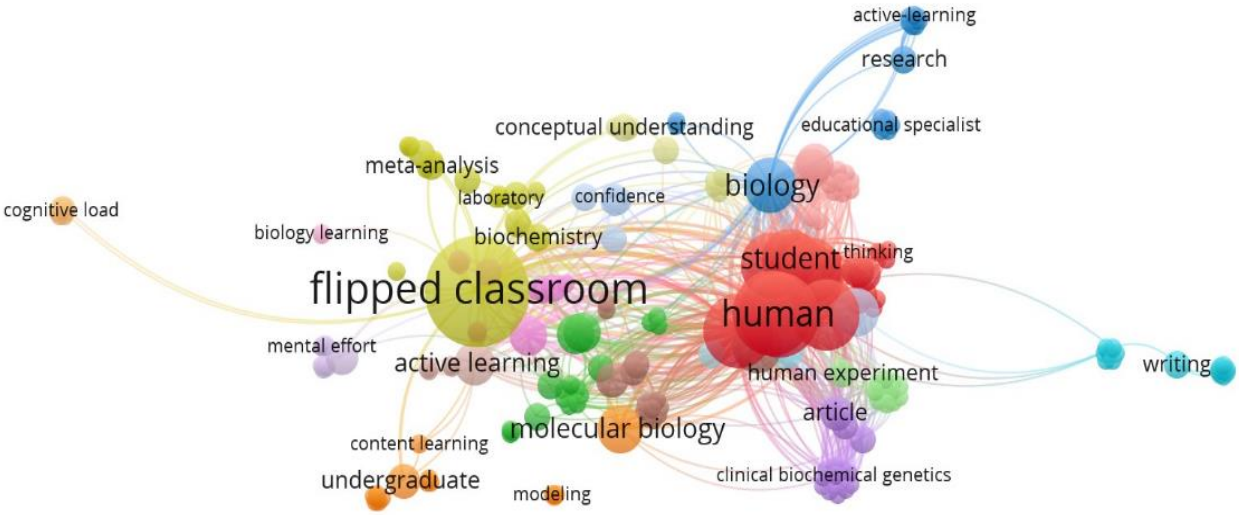

Figure 3. VOSviewer display for the type of analysis "co-occurrence → keyword" (Source: Results of researcher elaboration, using VOSviewer software).

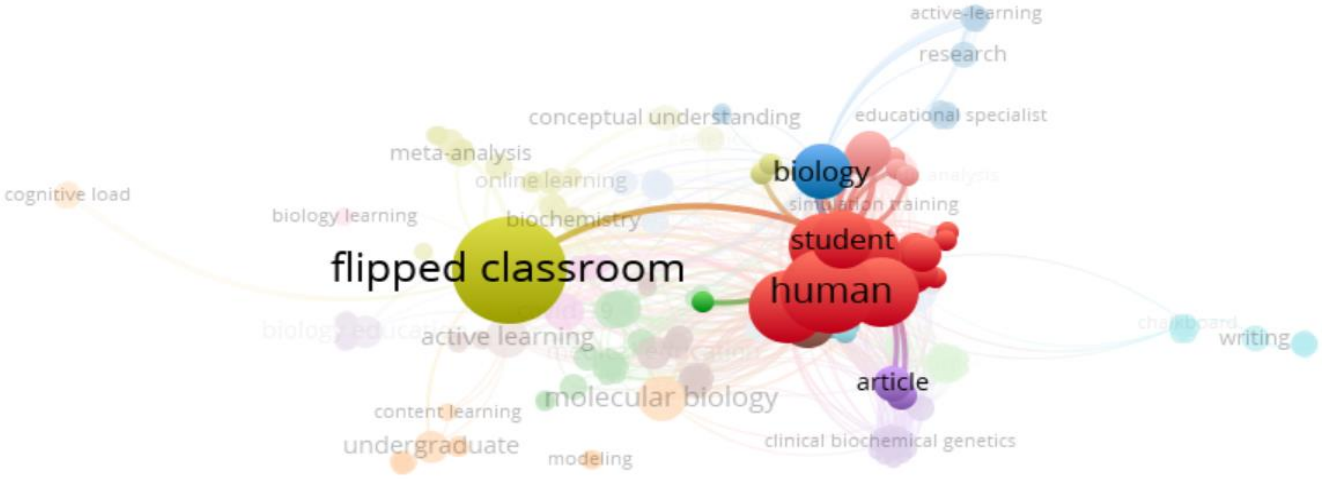

Figure 4. VOSviewer display for the type of analysis "co-occurrence → keyword: CO" (Source: Results of researcher elaboration, using VOSviewer software)

Figure 4 also provides an explanation that the keyword FC also has a fairly strong connection with the discipline of biology. The FC is a strategy that seeks to be integrated into several branches of biology. The keywords student and human are highlighted which strengthens that researchers are trying to connect/apply the FC to students as individuals who want to be empowered in the learning process. This relationship needs to be reviewed so that it provides an in-depth picture for readers or researchers who are interested in the field of FCs in biology learning.

There are 4 main keywords that dominantly appear and are interrelated with "FC and Biology", namely student, human, biology, and active learning. Students become important objects in the FC application in biology learning. This learning strategy places students in a strategic position to have full involvement in learning both outside the classroom and inside the classroom (Loveys & Riggs, 2019; Županec et al., 2018). Talking about students directly also links the FC with students as humans. Learning using the FC supports students' humanistic abilities such as problem-solving skills, critical thinking, and understanding biological concepts (de Vries, 2023; Goff et al., 2018; Karaoglan-Yilmaz et al., 2023; Ristanto et al., 2022; Styers et al., 2018). Apart from that, the interactions that arise in the FC learning environment in biology learning increase interaction between students and teachers, as well as between fellow students, thus training communication skills and developing students' social intelligence as whole humans (Ebrahim & Naji, 2021).

The keyword FC is related to biology, indicating that the FC is trying to be applied in the study of biology. This is natural because biology contains complex material that requires in-depth understanding with more time. Thus, the presence of the FC is a way for students to prepare themselves by studying basic concepts before class meetings and utilizing class time for in-depth discussions, applying concepts in complex ways (Förster et al., 2022; Gariou-Papalexiou et al., 2017). The process that students go through implies that the FC has a strong relationship with active learning, where the focus is on supporting learning contexts such as independent learning, collaborative and practical learning as well as interactive learning involving technology (Betti et al., 2022; Candel et al., 2023; Sletten, 2017).

Researcher Nationality and International Collaboration

Research trends related to the nationality of the authors related to the theme "FC and biology" are presented in Table 2. Based on Table 2, it is shown that there are 9 countries of origin of the authors. In percentage terms, the number is only 4.66% of the total 193 countries in the world. The top ranking in publications related to the FC theme in biology learning is the United States (11 articles).

Table 2. Nationality and Continent of FC Research Authors in Biology Learning

No	Country	Continent	n Author	n Article
1	United States	America	41	11
2	Indonesia	Asia	8	2
3	Netherlands	Europe	5	2
4	Serbia	Europe	5	1
5	Australia	Australia-Oceania	4	2
6	Greece	America	4	1
7	Philippines	Asia	3	1
8	Kuwait	Asia	2	1
9	Brazil	America	1	1

If we examine the continental aspect (Figure 5), it is found that the American continent has the largest number of authors, namely 41 authors. Then, Asia has 13 writers and Europe has 10 writers. Meanwhile, Australia-Oceania only consists of 4 authors, while in Africa there are no researchers who have studied this matter. It is interesting because articles about the FC in biology learning were written by authors from almost all corners of the continent, indicating that this theme has its own class and urgency so it deserves to receive global attention.

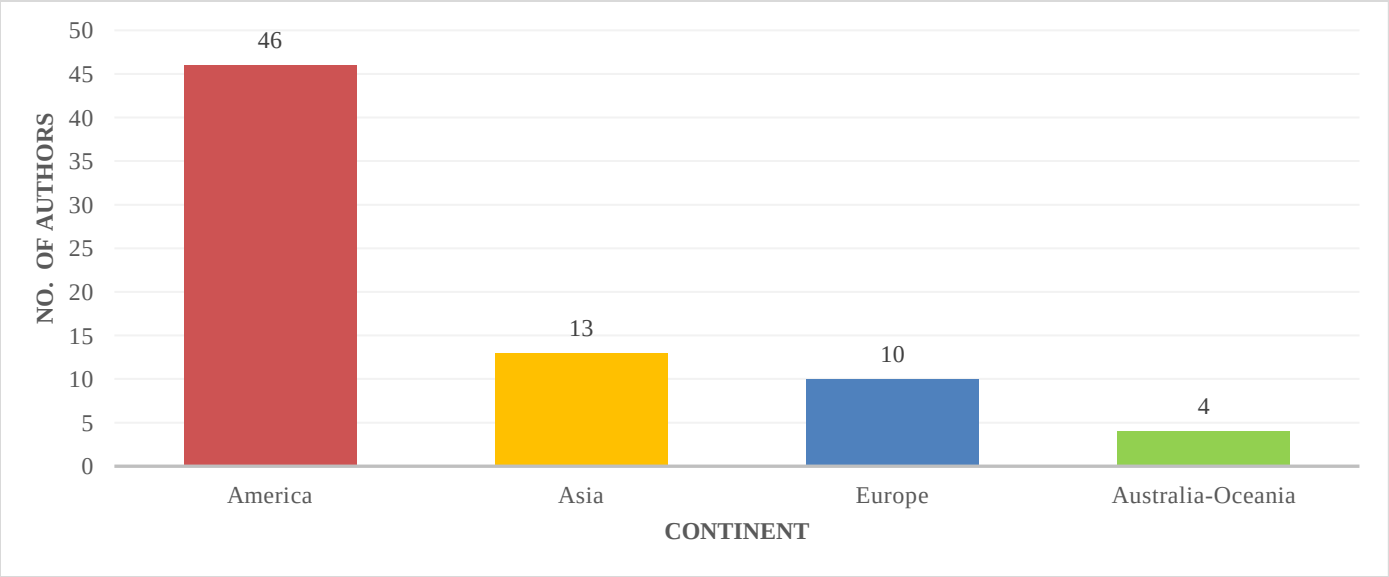

Figure 5. Number of authors from each continent (Source: Results of researcher elaboration, using Ms Excel)

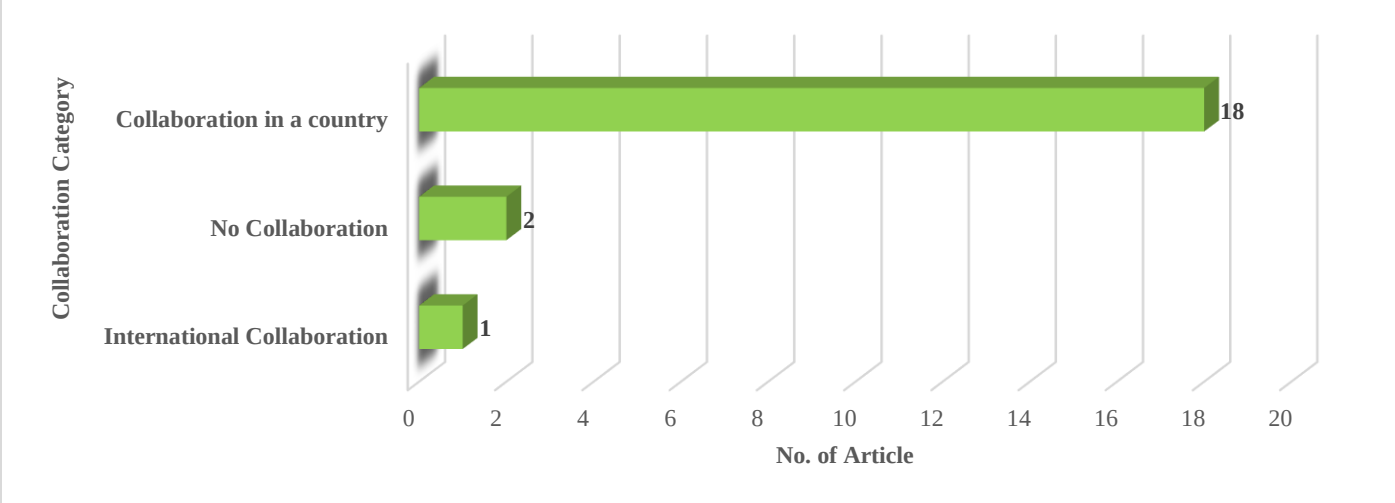

Figure 6. Collaboration of researchers in writing articles (Source: Results of researcher elaboration, using Ms. Excel)

Figure 6 shows the collaboration carried out by researchers writing articles, both cross-country collaboration, collaboration between universities in one country, and authors who carry out research/publications individually. Meanwhile, Figure 6 provides an overview of the number of researchers listed in one article.

Figure 7 is a picture that shows the number of researchers who participated in writing one article. Based on Figure 6, it can be understood that more articles are published in collaboration in a country or articles written arise from collaboration between universities in a country (18 articles or 85.71%). When analyzing the 21 articles that have been identified, it can be concluded that it is very rare to find articles originating from international collaborations (only 1 article or 4.77%). If you combine the percentage of non-collaborative writings (only 2 articles or 9.52%) with international collaboration, there is no significant change in that research related to this theme still tends to focus on the same country by combining the fields of knowledge that support it. success of the research carried out.

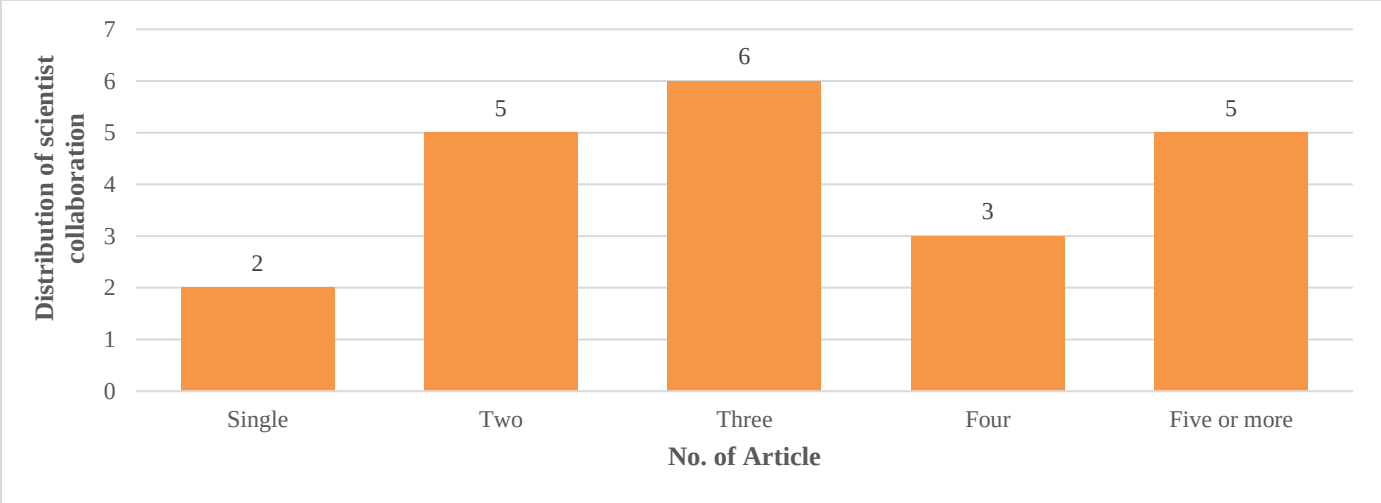

Figure 7. Collaboration of researchers in writing articles (Source: Results of researcher elaboration, using Ms. Excel)

The American continent is the country that has the most publications regarding the FC in biology learning, especially the United States. It must be acknowledged that the United States was the first country to popularize the FC (Bergmann & Sams, 2014). Apart from that, in the United States itself, technology policies created through innovative programs absolutely influence the way and design of learning that is implemented. The government guarantees the presence of technology-based learning and accommodates all citizens to obtain important benefits from this technology (Lundin et al., 2018). This technology policy seeks to ensure that every school has access to technology, teachers are skilled in integrating technology into learning, and instills awareness that technology supports effective and inclusive learning (U.S. Department of Education, 2017). So, it is not surprising that the United States is a country that actively publishes related to the FC because it has readiness in terms of both infrastructure and human resources.

Indonesia is recorded as having 2 publications related to the FC in biology learning. Like the United States, Indonesia shows commitment to integrating technology into learning through the Digital Literacy Movement program (Kemdikbud, 2017). Furthermore, Indonesia is active in conducting training on the use of technology in teaching targeting educational institutions and practitioners. Practitioners and even students are expected to be trained in making digital learning videos, managing online classes, digital-based interactive media and even virtual laboratories (Irhasyuarna et al., 2022; Lestari et al., 2023; Nugroho & Wilujeng, 2019). If explored further, this could be an important asset for designing FC learning in biology learning. Researchers also found an Indonesian-affiliated article that created a FC-based Game-Based Learning with biology content (Ristanto et al., 2022). Indonesia as an archipelagic country needs to ensure equal accessibility of learning. FCs can facilitate the implementation of distance learning. Therefore, strategic research on this theme must continue to be developed to create an image of a country that actively carries out research by considering the conditions of its region and population. When viewed from the continental aspect (Figure 5), researchers found unique data, where almost all continents have written about the application of the FC in biology learning. This shows that this theme attracts researchers' curiosity to conduct research and even combines it with other learning methods (S. A. de Araújo et al., 2023). The importance of the FC in biology learning as one of the best solutions when educational institutions are encouraged to adopt distance learning, such as during the Covid-19 pandemic (Poulain et al., 2023). This strategy must be a driving force that allows students to continue to access knowledge and carry out experiments to achieve their best skills (Sun et al., 2023).

The analysis results show that the Australia-Oceania continent only has 4 authors. Researchers did not find any published writings from the African continent. This is a signal that the application of the FC in biology learning needs to be encouraged on these two continents. In the context of Oceania, there are still remote areas where it is difficult to access education and overcome geographical challenges. In fact, if you look at the potential of the FC, it can be an alternative solution to overcome this gap. Students living in remote areas can access learning via the internet before coming to class, using PowerPoint slides and online video content that teachers have created in advance (Hao, 2016). On the African continent, several regions still face limited technological infrastructure, including internet access. Apart from that, limited human resources and professional abilities of educators are obstacles in adopting new learning strategies. This limitation needs to be highlighted by other countries such as South Africa, which since 2015 discovered the essence of the FC in general. Researchers report that learning strategies can increase understanding, apply theoretical concepts flexibly and improve problem solving abilities (Cilliers

& Pylman, 2022; Tanner & Scott, 2015). The hope is that South Africa and even the United States can collaborate with these countries to conduct research and publish FCs on biology learning through international collaboration projects.

Based on collaboration status, most articles are written and published collaboratively. Only 1 article written by one person was found. There are quite a lot of articles published by researchers from the same country or university. Even though they are in the same country, these articles show an effort to combine fields of knowledge to produce articles that are multidimensional. This is in line with Turan (2023) who believes that to get a wider impact from FC research in biology learning requires collaboration of scientists from different scientific fields. The FC allows for the potential for integration between learning technology, material analysis, and capable learning design (J. L. Jensen et al., 2018). These findings indicate that collaboration within one country must be maximized to show the consistency of researchers or educational institutions in that country in developing FC research in biology learning.

The unique information found was that only 1 article was found which was written in international collaboration. International research collaboration regarding the FC in biology learning must be increased. Collaborative research has a number of obstacles because the education system in each country has unique characteristics and different challenges. In addition, government priorities and directions regarding the creation of innovations and automated learning methods differ from one country to another. International collaborative research also faces obstacles in terms of language, funding, time zones and limited time to meet face to face (Ashraf et al., 2021). If these obstacles can be accommodated properly, a solid and unidirectional international community will be formed in enriching the research literature. This can be achieved through the development of a joint research framework

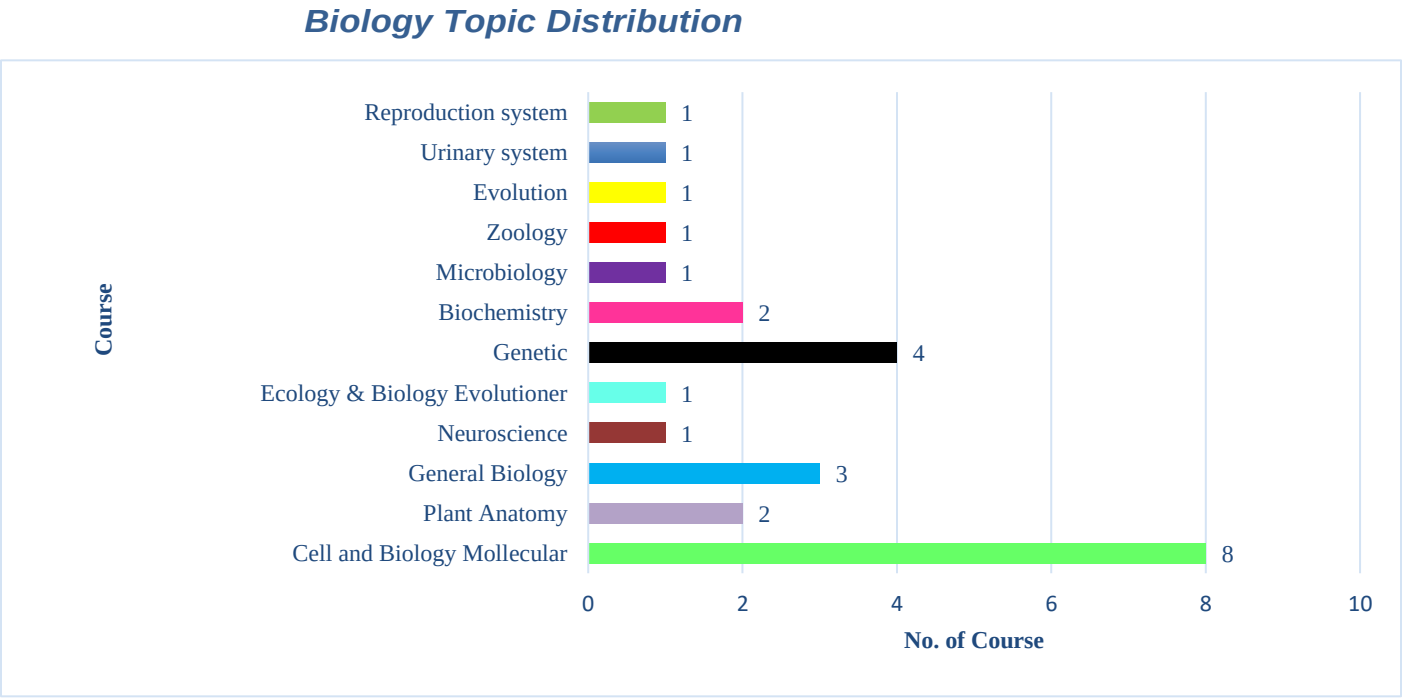

Figure 8. Distribution of biology topics using the FC (Source: Results of researcher elaboration, using Ms. Excel)

Figure 8 shows a study of biology taught using a FC. The author succeeded in discovering 12 branches of biological science. The three branches of biology that widely apply the FC based on the articles analyzed are cell and molecular biology with 8 articles. Then, genetics with 4 articles and an introduction to biology with 3 articles. The unique thing is that the branch of biology obtained has different characteristics, principles and objects. After identifying 21 articles, we concluded that the FC is a learning environment that is open to various contexts of biological material. Although currently not all published biology topics are taught using the FC. So, it can be said that researchers are interested in applying the FC to various kinds of biological science studies with different levels of difficulty, depth and breadth of material.

Cell and molecular biology topics are the material most studied in the FC. Researchers found 8 articles that were predominantly applied at university level. The choice of this material must have a deep reason. Biological concepts such as cell and molecular biology are complex systems and difficult to visualize.

This biological concept also contains certain sub-materials that try to relate cells to the scientific fields of chemistry, physics, and its relation to system functions (Momsen et al., 2022). Due to the strict classroom limits and study time in schools, the instruction given tends to focus only on the basic structural differences between animal, plant, and bacterial cells. This causes the emergence of students' habit of memorizing organelles and structures without seeing cells as an interconnected system (Cohen, 2015). The topic of genetics is in second place as material taught in the FC. Genetics is a branch of biology that has a broad and complex scope of material. Genetics also contains abstract sub-material and even requires mathematical abilities in Mendelian genetics (Williams et al., 2012). The topic of genetics is considered the most difficult and difficult subject for both education and non-education students because it contains many concepts that are difficult to understand (Fauzi & Fariantika, 2018). As a result, students are encouraged to participate in learning activities that are not meaningful and take responsibility for their education (Lai & Hwang, 2016)

If we examine the material characteristics of cells, molecular biology and genetics, there are similarities that result in students having difficulty learning and understanding concepts optimally. This characteristic makes teachers need more time to transfer knowledge and experiment to ensure the achievement of meaningful learning (Mennella, 2016; Rojas, 2023). More time provides special benefits for students to process information critically and inspires true active learning (Leatherman & Cleveland, 2020; Styers et al., 2018). Transmission of information outside the classroom makes students come to class well prepared and ready to explore the material in an applicable context. Students can watch videos and play them over and over again, access unlimited scientific literature, diverse e-books at the time and place of their choice (Anderson et al., 2021; Bouwmeester et al., 2016; Goff et al., 2018; J. L. Jensen et al., 2018). The analysis carried out makes the author predict that publishers tend to be interested in accepting articles about FCs with difficult material. This could be an opportunity for other researchers to continue to increase the number of publications containing material that is vulnerable to misconceptions using the latest methods.

The unique information found was that there was only 1 article that used ecological material. Ecology is a study that studies the diversity of living things and the interactions between living things and their abiotic and biotic environments (Begon & Townsend, 2021). Ecology includes areas such as conservation biology and global warming that are synonymous with field experience (Courchamp et al., 2015). Field experience provides benefits for students because they can directly observe certain objects in the field (Race et al., 2021). Field experiences in ecological learning must be developed with new methods or approaches that are in line with technological developments (Lashley & McCleery, 2020). If we reflect on the Covid-19 pandemic, of course ecological material will be an interesting topic to explore in a FC. Ecological scientists are forced to think about how to deliver ecological material but still maintain field experience in a safe and intensive manner. Future researchers can take advantage of this momentum to publish additional articles that innovate FC-based ecological learning.

The Existence of the FC in Biology Learning

Researchers analyzed 21 articles and tried to collect various information on the extent of the implementation of the FC in biology learning today. Table 3 presents key information obtained from the 21 articles reviewed. There are 4 things that can be formulated regarding the FC in biology learning.

Table 3. Important information from each article

No	The Relation of Important Information to Existence	The Relation of Important Information to Existence
1	The out-of-class learning phase increases self-confidence and shapes students into competent readers of cell material (de Vries, 2023)	The FC has the potential to empower all student competencies, namely cognitive, affective and psychomotor in biology learning
2	The FC has a positive impact on student self-efficacy and learning outcomes (Ridlo et al., 2022)	
3	The FC stimulates students' self-confidence and becomes a driving force for increasing students' motivation to be actively involved in learning (Awidi & Paynter, 2019)	
4	The instructional design created by the instructor aims to empower students' self-regulated learning (Sletten, 2017)	
5	The FC facilitates students understanding basic concepts before entering class and remembering biology vocabulary (Barral et al., 2018)	
6	The application of the FC in learning accommodates student involvement in learning and improves learning achievement (Županec et al., 2018)	
7	The FC model is an effective model for maintaining the essence of learning in the field on ecology and evolutionary biology material through intensive laboratory experiences (Lashley & McCleery, 2020)	
8	The integration of flipped learning into laboratory activities increases student engagement with more time (Loveys & Riggs, 2019)	
9	Learning designed using a FC improves student performance compared to learning designed	

No	The Relation of Important Information to Existence	The Relation of Important Information to Existence
	using Asynchronous Online Instruction (Jensen et al., 2022)	
10	The application of active learning in the FC provides benefits in developing students' critical thinking skills both outside the classroom and in everyday life (Styers et al., 2018)	The FC phase in biology learning has the potential to empower 21st century skills (such as problem solving, critical thinking, collaboration, and digital literacy)
11	The Inquiry-based flipped learning model combined with the FC provides benefits for teachers in teaching biology topics with limited contact time to improve students' understanding of concepts and science process skills (Tan et al., 2020)	
12	The use of the FC strategy accommodates the formation of students' social skills to minimize interpersonal conflict between groups (Ebrahim & Naji, 2021)	
13	FC learning significantly forms students' positive attitudes towards ICT and time management (Gariou-Papalexiou et al., 2017)	
14	The use of textbooks in FC learning improves student learning experiences (Eichelberger & Ngo, 2020)	The implementation of the FC in biology learning can be integrated with interactive digital media and teaching materials
15	The use of online modules in FC learning increases students' understanding of cell concepts (Goff et al., 2018)	
16	Instructional videos in the pre-class phase motivate students to understand the learning material quickly (Bassett et al., 2020)	
17	The use of interactive guides and textbooks is more effective than the use of video lectures in the pre-class phase of FC learning (Jensen et al., 2018)	
18	Pop-Up Questions attract students' attention in watching videos during pre-class and improve student learning outcomes (Haagsman et al., 2020)	
19	FC learning combined with Digital Game Based Learning becomes an evaluation tool to check students' understanding of concepts in genetics material that is presented in an interesting and competitive manner (Ristanto et al., 2022)	
20	FC learning becomes more ideal if combined with course-based undergraduate research experiences (CURE) which are presented virtually (Waddell et al., 2021)	
21	Evaluation of the sustainability of the FC needs to be carried out by considering students' socio-economic status to ensure student comfort and learning achievement (Jensen et al., 2015)	The FC in biology learning has challenges in terms of the accessibility of the technology used

The results of the analysis (as seen in Table 3) show four important points regarding the existence of the FC in biology learning. First, the FC applied in biology learning has the potential to empower students' affective, psychomotor and cognitive abilities. Learning activities outside the classroom provide opportunities for students to actively participate in managing their own study time at home (Gariou-Papalexiou et al., 2017). Efforts to independently prepare and understand material before class sessions give students greater control over their own time, rhythm, and learning style. Learning independence helps students build self-confidence because they feel they have ownership of the learning process as a whole (Awidi & Paynter, 2019; de Vries, 2023). Affective abilities are also instilled in students during the learning process in the classroom. Students focus on carrying out a series of activities that bring out their social skills and absorb situations that require certain emotional responses (Al-Zahrani, 2015; Ebrahim & Naji, 2021). The way students maximize their social skills initiates the birth of leadership traits, such as when distributing group tasks and making decisions. So, it can be ensured that students who have a leadership spirit within themselves have high academic performance and self-efficacy (Dunbar et al., 2018; Ridlo et al., 2022).

The application of the FC in biology learning has been proven to improve cognitive abilities. The use of instructional videos as pre-class learning materials becomes a pedagogical practice that facilitates students to carry out fundamental knowledge construction (Liao & Wu, 2023). The opportunity to access learning materials outside the classroom allows students to reflect on their higher-order thinking skills, such as the ability to understand, process, analyze and evaluate information flexibly. These cognitive activities lead students to achieve the best understanding of basic concepts before engaging in further knowledge construction (Barral et al., 2018). In the classroom, the symbol of knowledge construction is that there is an in-depth discussion led by the teacher regarding certain biological issues that absolutely uses basic knowledge to find potential solutions (Bergmann & Sams, 2014; Hwang et al., 2015). Group discussions and interactive project-based activities stimulate students' analytical power in understanding biological concepts in depth. This supports students' ability to remember information better. Zainuddin and Halili (2016) highlighted that group discussion activities in the FC allow students to have more time to experience high-level learning. Active student involvement not only increases students' understanding of biological concepts, but also adds to learning experiences that require psychomotor skills. Virtual simulation activities, projects and practicums in the laboratory provide students with the opportunity to hone their psychomotor skills. Activities in the laboratory, whether presented virtually or in real life, have

the benefit of consolidating their knowledge and connecting theoretical concepts with real world situations (Lashley & McCleery, 2020).

Second, the implementation of the FC in biology learning has the potential to empower 21st century skills. Biology learning activities in the classroom are designed to carry out problem solving activities. Students are challenged to hone their thinking skills in conceptualizing given problems, designing strategies to solve problems, and evaluating the strategies implemented (Gürsan & Yazgan, 2020; Simamora et al., 2018). During the problem-solving process students will use their thinking skills to create a list of questions to produce logical ideas. The way students solve a problem involves critical thinking skills which are also a necessity for 21st century learning. Critical thinking skills in active learning strategies help students to explore various points of view by analyzing facts, being selective in deciding what is right and wrong, what needs to be followed and abandoned more carefully (Eichler & Peeples, 2016; Styers et al., 2018). The implementation of the FC in biology learning, if viewed from critical thinking skills, also provides other benefits, students not only understand knowledge but also transform knowledge such as achieving reflective thinking skills (Bi et al., 2023; Suryanti & Nurhuda, 2021).

In the FC, students are routinely directed to work collaboratively, using instructional methods that require effective communication (Birgili et al., 2021). Collaboration is carried out as a way to construct knowledge based on social interaction in work groups (Ebrahim & Naji, 2021; Hwang & Chen, 2019). The social interaction that exists trains students to reduce individual attitudes at work, be responsible for the workload they receive, have the courage to trust their friends and minimize interpersonal conflicts that can disrupt group stability both face-to-face and using the help of digital devices (Ay & Dağhan, 2023; Shin et al., 2022). The FC applied to every scientific subject, including biology, cannot be separated from the integration of technology. Assimilation of knowledge using technology helps students become digitally literate (Gariou-Papalexiou et al., 2017). Student participation goes even beyond just operating the LMS. Online discussion activities, online quizzes, use of modules and other digital teaching materials facilitate students to be able to evaluate reading material information effectively, verify the credibility of information, differentiate between facts and opinions and select credible information (Alt & Raichel, 2020; Webb & Doman, 2020). This is the essence of digital literacy which is widely discussed as a life skill for the 21st century today.

Third, the implementation of the FC in biology learning can be integrated with interactive digital media and teaching materials. In FC learning, instructions for online learning can be given in various forms, such as digital teaching materials (instructional videos, textbooks and modules). Instructional videos are often used to deliver material because of the preference of millennials or generation Z who prefer to learn by watching videos (Londgren et al., 2021; Seemiller & Grace, 2017). Students feel they have full ability to pause the video and watch it according to their learning rhythm (Aljaber et al., 2023; Bassett et al., 2020). Videos shared with students become more effective if they are accompanied by learning activity sheets or Pop-Up questions. This is done to help students achieve better understanding of concepts and academic performance (Deng et al., 2023; Haagsman et al., 2020). Textbooks and digital modules can also be a choice of teaching materials to distribute basic knowledge to students before entering class. Reading materials, which are often referred to as the backbone of every educational institution, actually make it easier for students to access material continuously, concisely and structured to read, and become a credible guide when studying independently (Eichelberger & Ngo, 2020; He et al., 2016; Jensen et al., 2018). Apart from using digital teaching materials, Digital Game Based-Learning in a FC situation creates an active, interesting and competitive evaluation space (Licorish et al., 2018). This media innovation facilitates students to achieve predetermined biology learning goals, accommodates the emergence of a competitive spirit that reaches various student characteristics, and minimizes learning difficulties due to the heavy weight of biology material (Boden & Hart, 2018; Orhan Göksün & Gürsoy, 2019; Ristanto et al., 2022),

Fourth, the FC in biology learning has challenges in terms of the accessibility of the technology used. Transforming a classroom into a FC requires digitalization of active and exploratory learning. Digitization requires audiovisual equipment that takes time and effort to compile, record, and edit instructional guides. Maintenance of the digital system used needs to be involved during the learning process to ensure student comfort in the learning process. Without reducing the important value of the FC, asynchronous learning carried out outside the classroom absolutely requires internet costs that must be borne by students. In fact, the important essence of the learning to be achieved is the momentum where students gain good knowledge. So, accessibility to technology needs to take into account the unequal socio-economic status of students. Instructors need to consider the extent to which these innovations can address each student's technology gap (Jensen et al., 2015).

Conclusion

This SLR provides interesting information. First, it can be seen that there is a fluctuating trend in the number of publications about the FC in biology learning from year to year. Second, it was found that the dominant type of research used was quantitative research, followed by mixed method research. The

implementation of the FC in biology learning needs to be achieved by looking at a holistic explanation regarding the treatment given, so that to get a comprehensive explanation regarding the application of this learning strategy, researchers combine a quantitative approach and a qualitative approach, this is what is called a mixed-method approach. There are also case studies and qualitative research only. Third, the author can identify that the keywords generally used by the author are student, human, biology and active learning. All of these key words have a strong relationship with each other. Fourth, the author found that there were 9 author countries. The highest ranking in publications regarding the FC theme in biology learning is the United States, while other countries have relatively the same number of published articles. Based on continents, it can be said that this theme attracts the attention of researchers globally. Although based on the data found, it shows that there is an inequality that places America as the continent that has the most writers. Asia and Europe respectively 13 and 10 authors. Australia-Oceania is very few, while in Africa there are no writers at all who have published on this theme. Fifth, the author found that most of the articles were published collaboratively. Collaborations carried out predominantly come from the same country. Writers can examine that collaboration is carried out by combining fields of knowledge that support the credibility of the articles written. Sixth, the author found that the dominant biology topics taught using the FC were cell and molecular biology, genetics and general biology. All material has a broad and complex scope so that it often makes students experience learning difficulties. Seventh, the author succeeded in formulating a picture of the existence of the FC in biology learning over the last ten years.

The results of the analysis of this article can be a consideration or reference for researchers to explore and study more deeply research related to FCs in biology learning based on their respective urgency. Future researchers can use information about article trends, types of research, keywords, collaboration between authors, and distribution of biology topics as reflections and references to develop research related to FCs in biology learning. The information contained in this article can be a guide for researchers in determining upstream and downstream research to be developed. The articles analyzed can be an illustration of how future researchers behave and see this publication trend as an opportunity and challenge to produce research updates in greater quantities. Like looking from the perspective of other research variables that have not yet been studied. Of course, this will be an interesting thing for further analysis.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions.

Three authors contributed equally to all research, collecting data, data analyze and writing processes. **M.W Jasman:** writing original article, collecting data, review, and revision; **S. Sulisetijono:** methodology, collecting data, review; and **S. Mahanal:** writing original article, collecting data, and review the manuscript.

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