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Bibliometric Review Analysis of Academic Outcomes of Flipped Classroom in Physics Education Before and During Covid-19

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Abstract – *The pedagogical approach known as the flipped classroom has gained significant popularity in both higher education and high school settings in recent years. This article aims to provide a comprehensive explanation regarding the comparison of flipped classroom academic results in physics education before and during the Covid-19 pandemic. The method used here was bibliometric-based literacy analysis using Publish or Perish (PoP) software and the VOSviewer application, which is focused on the keyword "Flipped classroom in physics" during the last three years before the Covid-19 pandemic (2017 - 2019) and the last three years during the Covid-19 pandemic (2020 – 2022). According to the findings of bibliometric analysis and systematic reviews of articles, the following flipped classroom academic outcomes in physics education were most frequently studied before the Covid-19 pandemic: 1) academic achievement, 2) motivation, 3) students' engagement, 4) students' performance, 5) knowledge acquisition, 6) interest in learning, 7) problem-solving skills, 8) self-efficacy, 9) conceptual understanding, and 10) attitude. Meanwhile, there are eight categories of outcomes in 2020-2021: 1) motivation, 2) academic achievement, 3) student experience, 4) student engagement, 5) conceptual understanding, 6) self-efficacy, 7) process skills, and 8) critical thinking. This study concludes that the academic outcome of flipped classroom research in physics education before the pandemic was more than during the Covid-19 pandemic, and in 6 past years, most research has focused on the effect of flipped classrooms on academic achievement, motivation, conceptual understanding, and self-efficacy compared to other academic outcomes such as scientific reasoning or creative thinking.*

Keywords: *academic outcome; bibliometric; covid-19; flipped classroom*

I. INTRODUCTION

All activities, including physics instruction, must change during the Covid-19 pandemic. This condition forces the student learning environment to migrate towards a more dynamic online-based learning model. This significant change in conditions has caused various parties, both students and teachers, to experience discomfort during learning. According to research by Mendoza-Lizcano et al. (2020), online-based learning has an emotional impact on students, with an 88.56% influence on decreasing student learning outcomes and cognitive abilities in

learning physics. The study conducted by Sari et al. (2022) also found that during the Covid-19 pandemic, the average cognitive ability of students learning physics online with e-learning declined, with up to 72.38% of students at SMAN 12 Bone falling into the low category. Following up on these shortcomings, various efforts have been made to improve the quality of online learning, one of which is by using the flipped classroom pedagogical approach.

A flipped classroom (FC) is a method of transforming traditional learning practices by substituting pre-class materials for classroom instruction. This allows students to progress at their own speed and provides opportunities for more collaborative and interactive learning experiences (Barrios et al., 2022). FC is an active learning strategy that reverses learning activities in the classroom with learning activities that are usually carried out outside the classroom (Cheng et al., 2019; Jensen et al., 2018; Reidsema et al., 2017; Slisko, 2017; Wright & Park, 2021). FC is considered blended learning, which is an innovative solution to time constraints in science learning (Gürsoy & Göksün, 2021; McCredden et al., 2017; Wright & Park, 2021). This is because the instruction that occurs outside the FC classroom is conducted online, so explicitly providing content information can provide more time for teachers to facilitate students to learn actively in the classroom (Zhu, 2021). FC offers a more interactive learning environment for students, which may lead to better learning outcomes and better learning preparedness for the 21st century (Al-Shabibi & Al-Ayasra, 2019).

In recent years, FC has become a popular pedagogical approach used in higher education and high school classrooms. Before the Covid-19 pandemic, FC was already being implemented in various contexts, such as teaching medical statistics and introducing students to thermodynamics (Lemley et al., 2013). The pandemic has accelerated the adoption of FC in science education due to the need for educational institutions to transition to distance learning (Azmin et al., 2021; Barrios et al., 2022). FC has also been implemented remotely during the pandemic, and the term "Remote Flipped Classroom" has been proposed to describe this mode of learning in an online environment, particularly in emergency situations (Karalis & Raikou, 2021). Research by Barrios et al. (2022) and Elgrably & Oliveira (2022) on software learning and engineering courses suggests that FC can be an effective approach to teaching physics remotely during the pandemic. However, these studies also highlighted the importance of careful design and curation of pre-class materials in online learning. Another study about teachers' perceptions of online teaching during the pandemic also shows that internet access, combined with some technical difficulties, poses challenges in the implementation of FC (Yadav et al., 2021).

However, despite the challenges, the FC has become an even more relevant and

valuable approach to physics education in the context of the Covid-19 pandemic. Before the pandemic, the improvement of cognitive abilities was the main focus of physics education research when compared to the development of FCs, while during the pandemic, the use of FC has increased, but research on cognitive outcomes has decreased (Birgili et al., 2021; Cheng et al., 2019; Lai & Foon, 2019; Subramaniam & Muniandy, 2019; Wright & Park, 2021; Zhu, 2021). A synthesis of the literature between 2010 and 2019 shows that the lack of variety of comparison groups in FC research (mostly FC vs. traditional) has an impact on the lack of theory that shows the development of FC design on cognitive thinking abilities (Meral et al., 2021). FC research conducted by Zheng et al. (2020) between 2013 and 2019 also reveals that 85.26% of the traditional FC model is employed more than the creative FC.

In light of the previously mentioned, the question arises of how the development of FC in physics education during the Covid-19 pandemic and whether the academic results of FC-based online learning in physics education during the pandemic were more varied than before the pandemic. Therefore, the purpose of this article is to provide a comprehensive explanation regarding the comparison of FC academic results in physics learning before and during the Covid-19 pandemic through bibliometric-based literature analysis.

II. METHODS

This study is a literature review on the comparison of academic outcomes of physics learning with FCs before and during the Covid-19 pandemic. This study uses bibliometric-based literacy analysis. Bibliometric analysis literacy review is a systematic and explicit method of systematic review (Garza-Reyes, 2015; Jamali et al., 2015). The data collection method in this study used the five steps of the bibliometric analysis method by Setyaningsih et al. (2018) and Haryandi et al. (2021), which can be seen in Figure 1.

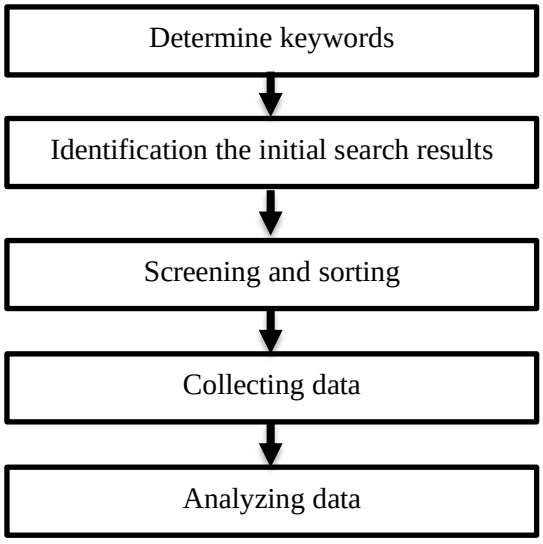

Figure. 1 Flowchart of the five stages of the bibliometric analysis method

The data collection process in this study uses Publish or Perish (PoP) software and the VOSviewer application. POP is used to collect the literature database that will be used. Meanwhile, VOSviewer was used to visualize literacy distribution patterns. The output documents from the PoP software were analyzed using VOSviewer software to determine the most frequently used search keywords. The search keywords used in VOSviewer were specifically used for data collection and analysis purposes. VOSviewer serves as a medium for visualizing maps from bibliometrics.

Determining keyword

The literature search began by searching from the Crossref database on POP software. The literature search focused on the keyword "Flipped classroom in physics" during the last three years before the Covid-19 pandemic, from 2017 - 2019, and the last three years during the Covid-19 pandemic, from 2020 - 2022.

Identifying initial search results

Based on the results of data identification, it was found that the 2017 - 2019 Crossref database obtained 5760 articles about FC. Meanwhile, for the 2020 – 2022 Crossref database, there are 8439 articles about FC.

Screening and sorting

The articles are then further selected based on keywords and fields, which in this case is in the field of physics education. Finally, 33 articles were retrieved for the Crossref database from 2017 to 2019, and 40 relevant articles were obtained for the Crossref database from 2020 to 2022. The sorting results were saved in the Risk Information System (RIS) format. The data from the RIS was then exported to the Mendeley desktop software for further analysis.

Collecting data

For data collection, the Mendeley desktop software allows for the examination of RIS-formatted data through a sequential review process. In the case of missing metadata, it becomes imperative to modify the metadata in order to align it with the metadata of the published article. The results of the editing process are also stored in RIS format.

Analyze data

In order to conduct data analysis, the data in RIS format, which had been modified using Mendeley Desktop, was subjected to additional analysis using VOSviewer. This process resulted in the generation of a bibliometric map visualization that provided a full overview of the data.

III. RESULTS AND DISCUSSION

The results of data collection from POP in the form of an article literacy database from 2017 to 2019 and 2020 to 2022 are shown in Table 1.

Table 1. Comparing POP crossref metric database between 2017 – 2019 and 2020 - 2022

Metric data	2017 - 2019	2020 - 2022
Keyword	*FC in physics education*	*FC in physics education*
Number of articles	33 of 5706	40 of 8439
Citation/ year	651.2	531.5
Citation/ paper	3.26	1.06
Authors/ paper	1.93	2.27
h-index	25	13
g-index	46	19

Based on the level of relevance and the number of citations that refer to the article, 10 articles were mapped that could be used as a comparison of the results of research on FC in physics education before and during the Covid-19 pandemic. Ten articles of FC on physics education before the Covid-19 pandemic can be seen in Table 2.

Tabel 2. Top 10 article research of FC on physics education before covid-19

Year	Author	Title	Academic outcome
2018	Prasetyo et al.	The effectiveness of flipped classroom learning model in secondary physics classroom setting	Motivation, interest to learn physics, student engagement
2018	He et al.	Innovation method of architectural physics teaching based on flipped classroom idea	Comprehensive ability and conceptual understanding
2019	Finkenberg & Trefzger	Flipped classroom in secondary school physics education	Motivation and self-concept
2017	Minaz et al.	An experimental study of the performance of prospective teacher of flipped classroom and non-flipped classroom	Performance student
2019	Rachmawati et al.	Flipped classroom in mathematics instruction: teachers' perception	Motivation, active learning, critical thinking skills, problem-solving skills and conceptual understanding
2019	Musdi et al.	Students' perception toward flipped classroom learning	Interest in learning physics, students' self-efficacy, learning achievements
2019	Montalbano & Marinelli	A flipped-classroom pilot in spectroscopy course for undergraduates	Students' engagement and critical thinking.
2019	Astra & Khumaeroh	The effect of flipped classroom model on student's physics learning outcome in work and energy concept	Learning achievement and conceptual understanding

2019	Istiandaru et al.	Learning differential calculus using self-regulated flipped classroom approach	Student's self-regulated
2018	Bawang & Prudente	Students' understanding of physics concepts, attitude, engagement, and perception in a flipped classroom environment	Performance student, problem-solving skills, conceptual understanding, student engagement, and attitude

As we can see, Based on the results of the mapping of the top 10 relevant articles, one can see that three years before the Covid-19 pandemic in Table 2, FC's academic outcomes in physics education that tend to be studied include student motivation, student interest in learning, student activity and attitudes, student involvement, learning outcomes, student learning achievement, critical thinking ability, problem-solving ability, student performance, student self-efficacy, and student concept understanding ability. These results are in line with the scoping review conducted by Han and Røkenes (2020). Furthermore, the 10 articles on FC on physics education during the Covid-19 pandemic for the last three years can be seen in Table 3.

Table 3. Top 10 article research of FC on physics education during covid-19

Year	Author	Title	Academic outcome
2021	Pierratos	Encounter with a rectilinier uniformly acceleration in flipped classroom: enhancing students data processing skills	Students process skill
2020	Stöhr et al.	The polarizing effect of the online flipped classroom	Students performance and students experience
2021	Suroviec	Flipped classroom and electrochemistry education	Students engagement
2021	Başaran	Meta-thematic analysis of flipped classroom applications	Motivation, students' engagement
2021	Wu	Research on computer basic teaching in higher vocational education under the background of flipped classroom	Students performance
2021	Demir & Öksüz	Comparison effects of flipped and in-class flipped classroom models on academic achievement and planning skills	Academic achievement and planning skill
2021	Karalis & Raikou	Flipping the classroom remotely: implementation of a flipped classroom course in higher education during the covid-19 pandemic	Students' engagement and students' experience

2020	Bintang et al.	Analisis pengetahuan konseptual, prosedural, dan metakognitif siswa melalui pembelajaran integrasi flipped classroom dan PBL	Conceptual, procedural, and metacognitive knowledge.
2022	Sevillano-Monje et al.	The flipped classroom and the development of competences: a teaching innovation experience in higher education	Students' engagement, students' competence level, and conceptual knowledge
2022	Khairiah et al.	A comparison study: the effect of flipped classroom vs direct instruction model toward science concepts understanding	Conceptual understanding

As we can see in Table 3, the FC academic results of 3 years of physics education during the Covid-19 pandemic include student motivation, scientific process skills, student experience, student involvement, student learning outcomes, and understanding of concepts. The results of bibliometric analysis mapping from the Crossref database with three different visualizations from VOSviewer are presented as network visualization, overlay visualization, and density visualization. Figure 2a shows FC research on physics education for three years before the Covid-19 pandemic, while Figure 2b shows FC research on physics education for three years during the Covid-19 pandemic.

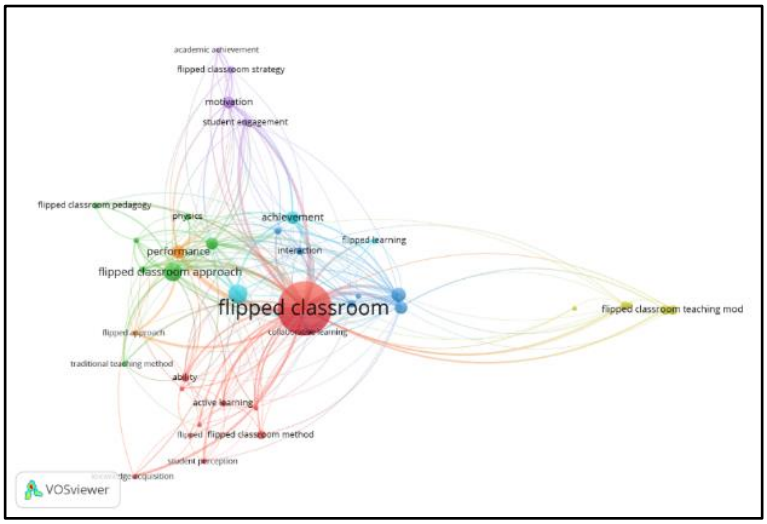

Figure 2a. Networks visualization of the FC in physics education 3 years before covid-19

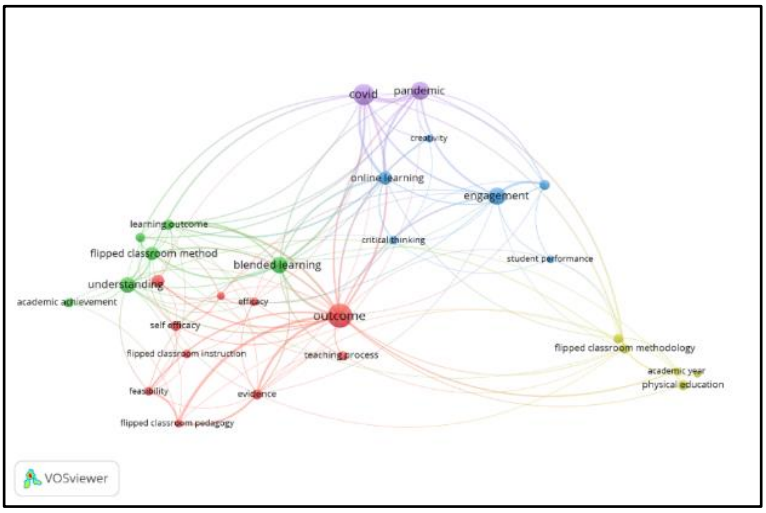

Figure 2b. Networks visualization of the FC in physics education 3 years during covid-19

Based on the network visualization in Figure 2a and Figure 2b, it was identified that in each image, there were 5 clusters characterized by 5 different colors: red, green, blue, yellow, and purple. Each color indicates the division of zones and the number of interrelated keywords (Haryandi et al., 2021). Keyword items that are closely related will be indicated by the same color. In this case, one can see that the cluster with red color has the most relationship, followed by green, blue, yellow, and then purple. Based on the network visualization, research on FC in physics education both before and during the Covid-19 pandemic is still related to several academic outcomes. When comparing the two, the variation in academic outcomes before the Covid-19 pandemic was more than in the last three years of research during the Covid-19 pandemic. The overlay visualization of FC in physics education three years before and during the Covid-19 pandemic is shown in Figure 3.

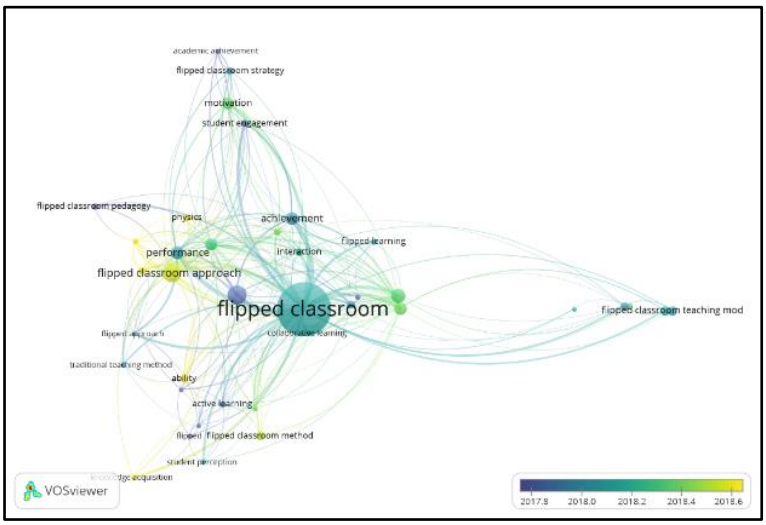

Figure 3a. Overlay visualization of FC in physics education 3 years before covid-19

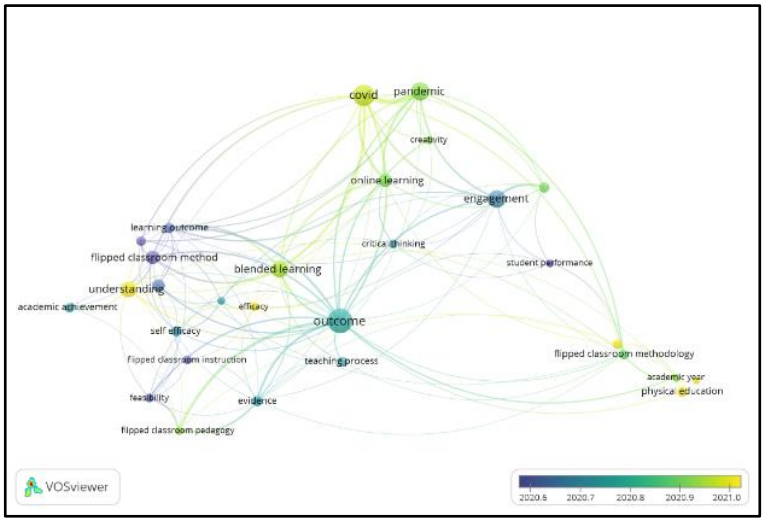

Figure 3b. Overlay visualization of FC in physics education 3 years during covid-19

The overlay visualization depicts trends in research keywords from year to year. The level of novelty of keyword publications is indicated by blue to yellow shades. The closer to yellow, the publication rate of research articles with that keyword becomes more recent. Based on Figure 3a, the FC trend in physics education occurred mostly between the end of 2017 and the middle of 2018, with turquoise as the dominant color. While Figure 3b shows that the majority of FC research publications in physics education occurred at the end of 2020, the distribution of color between 2020 and 2022 is nearly balanced. The density visualization of FC in physics education three years before and during the Covid-19 pandemic is shown in Figure 4.

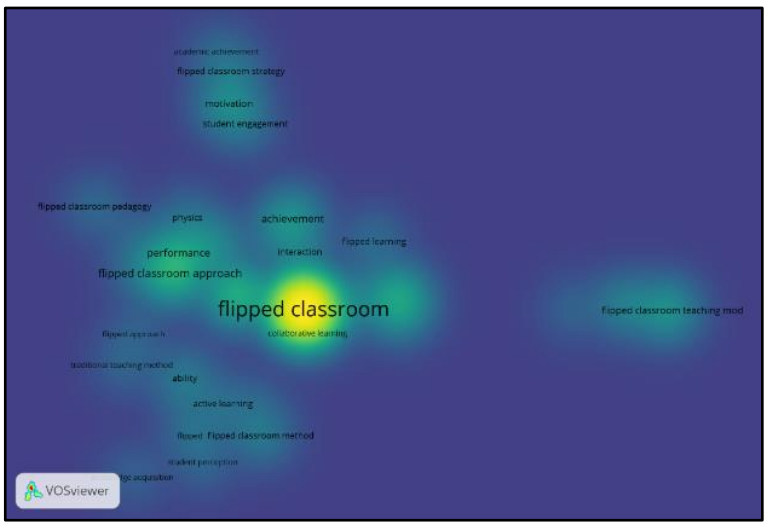

Figure 4a. Density visualization of FC in physics education 3 years before covid-19

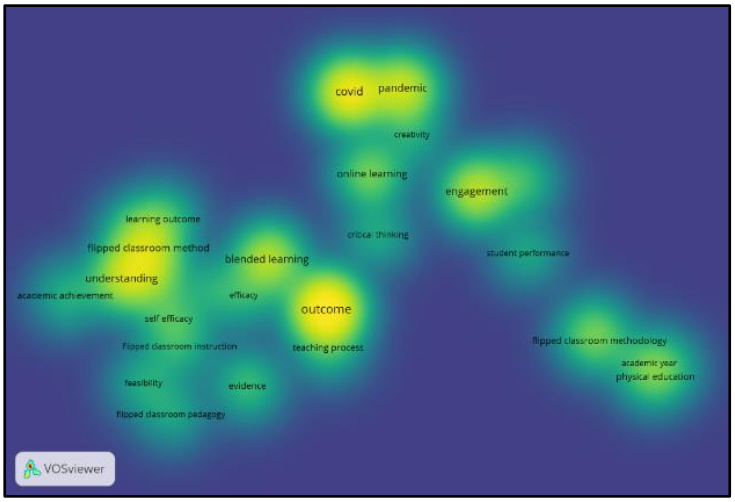

Figure 4b. Density visualization of FC in physics education 3 years during covid-19

Figure 4a and Figure 4b are the density visualizations showing the depth or closeness of research based on the keywords. If the yellow color is getting more and more concentrated, it means that more research is related to that keyword. Based on Figure 3a, one can see that before the pandemic, FC research tended to be closely related to collaborative learning discussions, where academic outcomes related to FC research in physics education before the Covid-19 pandemic, including academic achievement, motivations, student engagement, student performance, and knowledge acquisition.

On the other hand, the density visualization in Figure 3b shows that academic outcomes related to FC research in physics education include academics during Covid-19, including student engagement, student performance, academic achievement, understanding, self-efficacy, and critical thinking.

Based on the analysis results of this study, there are several things that can draw attention. First, there are differences in the intensity of physics education research involving the FC approach. There are more studies focusing on the academic outcomes of physics learning with FC before the pandemic compared to during the pandemic. Before the pandemic, a literacy review of the few studies that have been analyzed shows that traditional FC contributes more to improving students' learning experience in physics education. This model encourages active participation and engagement so students are better prepared for in-class discussions and problem-solving activities (Astra & Khumaeroh, 2019; Bawang & Prudente, 2018; Rachmawati et al., 2019). Meanwhile, FC research conducted during the pandemic shows that students generally accept online FC learning in physics education. The majority of students expressed their acceptance of this way of teaching, although some had reservations or concerns about the

selection and quality of pre-class materials (Azmin et al., 2021). Romadhon et al. (2022) research also showed that some students found it helpful in improving their understanding of the course material, while others found the methods and media used quite difficult to understand. This suggests that the FC approach can result in ineffective online learning if it is not designed carefully.

Second, this literacy review provides information that there is still little FC research that discusses its influence on scientific reasoning in the last 6 years. Network visualization and analysis, overlay, and density in this study provide an overview of FC research trends in physics education over the past 6 years, that is 3 years before and 3 years after the pandemic. Whether before or during the Covid-19 pandemic, most studies focused on the effect of FC on academic achievement, motivation, conceptual understanding, and self-efficacy compared to other academic outcomes such as scientific reasoning or creative thinking. Although motivation has a positive correlation to learning outcomes during online learning (Setyaningsih & Fauziah, 2022), cognitive abilities and skills are still a concern for physics education in Indonesia. In addition, based on data collected from the Crossref database in this study, it also shows that there are still rare studies examining FC in the field of physics education in Indonesia in the last 6 years. Especially during the pandemic, the intensity of research on Remote FC has become more trendy in science education in other countries. This does not indicate that FC research on scientific reasoning does not attract other researchers in Indonesia, given the fact that the weakness in this study is that the range of search years set is still relatively short (2017 - 2022). However, the results of this study may serve as reference material for future researchers in developing research on FC in physics education.

Overall, FC has shown potential to improve student learning experiences and encourage active participation in physics education, both before and during Covid-19. Moreover, this is supported by the majority of prospective physics teachers in Indonesia who already have good digital competence and are able to adapt the use of interactive technology in academic activities (Rahim & Yustiana, 2023). However, the transition to online learning has presented new challenges and considerations in implementing the FC model during the pandemic. The FC model can be successful in implementing physics education during and after the pandemic when careful attention is paid to the design and use of pre-class materials, the use of interactive tools, and the evaluation of student performance.

IV. CONCLUSION AND SUGGESTION

This study concludes that the academic outcome of FC research in physics education before the pandemic was more than during the Covid-19 pandemic. Before the Covid-19 pandemic, the following FC academic outcomes in physics education were most

frequently researched: 1) academic achievement, 2) motivation, 3) student engagement, 4) student performance, 5) knowledge acquisition, 6) learning interest, 7) problem-solving ability, 8) self-efficacy, 9) conceptual understanding, and 10) attitude. Meanwhile, during the Covid-19 pandemic, the following outcomes have been most frequently examined in physics education research with FC: 1) motivation, 2) academic achievement, 3) student experience, 4) student engagement, 5) conceptual understanding, 6) self-efficacy, 7) process skills, and 8) critical thinking. Furthermore, we also conclude that in the past 6 years (both before and after Covid-19), the majority of physics education research has focused on the impact of FC learning on academic performance, motivation, conceptual understanding, and self-efficacy relative to other academic outcome such as scientific reasoning or creative thinking.

For future research, researchers suggest using a greater number of samples by broadening the keywords used and databases accessed, such as those available in other databases, such as Scopus, or Microsoft Academic. Additionally, it is suggested to compare the results of the analysis using different bibliometrics analysis software (e.g., BibExcel or HistCite). Furthermore, bibliometrics can generate keywords used in classifying topics by affiliation, location, and country, resulting in more comprehensive data.

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