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"Let's transform!": A systematic literature review of science learning in COVID-19 pandemic era

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Abstract

Currently, the world's science learning is being affected by COVID-19 pandemic, which requires researchers to address it. Researchers' attention and concern for the theme of science learning is highly expected, as evidenced by the existence of publications in reputable journals. The purpose of this systematic literature review is to review and compare investigations of research on articles published by Scopus-indexed journals (published during COVID-19 pandemic: 2020-2022). The researchers used a "science learning" phrase in the search menu of Scopus database and 1,484 articles were found by the researchers. Furthermore, 62 articles met the criteria to be analyzed. The inclusion and exclusion model used was preferred reporting items for systematic reviews and meta-analysis. Based on the results of the analysis, we found that in the last three years, there had been a decline in research on science learning. The science issues could be approached through quantitative, qualitative, mix-method, case study, and even development research. Marianne Kinnula is the author who has received the most attention in the study of science learning. According to the data, it is known that science learning and science education keywords are the most dominant keywords that used in a publication. There are 36 countries of origin for authors who publish articles, with the majority coming from Europe, though Indonesia has the most publications (Asia). Science articles are written by authors from all over the world. It was discovered that more articles were published as a result of collaboration. There are 69 institutions globally that fund science learning research and publications. We offer three perspectives on transformation science learning during a pandemic that can be used as a baseline and reference by other researchers or education policymakers. As an implication, the second and third perspectives from transformation that we have formulated are interesting for further study.

Keywords: transformation perspectives, pandemic era, science learning, systematic literature review

INTRODUCTION

COVID-19 pandemic is affecting education all over the world. Millions of primary and secondary school students, as well as students at higher education institutions, are affected. (Engzell et al., 2021; Hammerstein et al., 2021; Russell, 2022). Particularly, COVID-19 pandemic affects the learning pattern (Coman et al., 2020; Engzell et al., 2021; Fahmalatif et al., 2021; Gonzalez et al., 2020; Kumar et al., 2021; Pokhrel & Chhetri, 2021; Wilczewski et al., 2021), and science learning is no exception (Canovan & Fallon, 2021; Chadwick & McLoughlin, 2021; Macias et al., 2022; Matuk et al., 2021; Roth, 2022).

Science learning needs to accustom with the demand of learning needs during the pandemic. Pandemic has generated various problems, ranging from pedagogical and psychological components to technical issues of connectivity (Abriata, 2022). Regardless, science learning with unique characteristics should be learned thru mind-on and hands-on (Adam, 2022; Arifin et al., 2022; Ermila et al., 2022; Muhlasin et al., 2022; Nur et al., 2022; Nurhayatus et al., 2022; Prasetyo et al., 2022; Varisa & Fikri, 2022). Hence, teachers should be able to create

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Contribution to the literature

- The researchers focus on the original publication about action competence for sustainable themes and its implications for environmental education for prospective science teachers, something that no other academics have done so that a study baseline may be provided.
- The review of the scope of material we utilize only contains research/original publications, offering an overview of the researchers' focus and alignments on this theme. The scope of information that the researcher use is limited to research/original articles; thus, it provides an illustration or description of the focus and partisanship of researchers regarding this theme.
- The researchers formulate a form or model of science learning transformation during COVID-19 pandemic so that it can be used as a reference or basis for the science learning process during a pandemic and as a post-pandemic consideration.

virtual, blended, and face-to-face classroom conditions that assist the students to maintain learning momentum even in crisis conditions (Wisanti et al., 2021).

COVID-19 pandemic is a challenge for teachers, lecturers, the government, and those involved in education to take adaptive and transformative actions (ECLAC-UNESCO, 2020; Iivari et al., 2020; Mishra et al., 2020; Pradhan et al., 2021; Sharif & Khavarian-Garmsir, 2020). In the absence of detailed guidelines or pre-configured playbooks that can guide them to produce the right responses, these adaptive and transformative actions or steps can be sporadic. When a pandemic is currently underway or in post-pandemic, educational actors must develop responses quickly (Reimers et al., 2020), and even how to deal with the next pandemic that may occur in the future (Bashir et al., 2021).

Researchers and science learning experts should also be responsive towards the learning challenges during a pandemic. A study on science learning that is in accordance with the needs, expectations, and the demand of pandemic era is needed (Gao et al., 2022; Reiss, 2020; Saputro et al., 2020). A study on science learning theme is needed to assist in discovering the implementation form of appropriate science learning and to discover the right solution to deal with the pandemic (Andriana et al., 2020; Apriani & Hidayat, 2022; Harto & Misbah, 2021; Husin & Yaswinda, 2021; Wijayanti et al., 2021).

Therefore, according to the results of a search on the Scopus database (the largest reputable journal database in the world) conducted in December 2022, there were 358 publications on science learning themes in the period 2020-2022 (out of a total of 1,484 for the all year's category). These publications are required to be analyzed in-depth to discover the form/model of science learning transformation during pandemic, aside from examining publication trends at the time (based on distribution year categories, research types/methods, authors and keywords, author nationality and international collaboration, funding sponsors). One of techniques that is highly recommended to study and analyze is by means of systematic literature review (SLR).

Up to this point, eight SLR-based articles about science learning have been discovered. There is one article published outside of the pandemic period (2016) and seven articles published during the pandemic (2020-2022). The first SLR focused on the use of mobile apps for science learning, and it examined articles published between 2007 and 2014 (Zydney & Warner, 2016). Another three articles are in the form of meta-analysis, which are focused on digital game-based science learning (Tsai & Tsai, 2020), augmented reality on science learning (Xu et al., 2022), and mobile users' pedagogical role on science learning (Shi & Kopcha, 2022). In line with those three SLR, there are two SLR focused on the findings and implications of flipped science learning research (Chen et al., 2022), immersive virtual reality for science learning (Matovu et al., 2022), and outdoor science learning activities with the integration of mobile devices (Kilty & Burrows, 2020). Thus, it can be stated that during COVID-19 pandemic, no SLRs focused on transforming science learning have been discovered.

Consequently, this SLR aims to review and investigatively compare various research on articles published by journals related to the theme of science learning and its implications in the form or model of transforming science learning during COVID-19 pandemic. This SLR is expected to provide contribution for the study development of science learning that can be a reference for the researchers and the readers of this topic. The researchers focus on the original publication of the articles in relation to the theme of science learning and its implications in the perspectives of transformation of science learning during a pandemic, something that has never been done by other researchers so that it can provide a research baseline. A review of the scope of the information that the researchers use only includes research/original articles, providing an overview of the researchers' focus and alignment on this theme. The researchers develop a perspectives science learning transformation during a pandemic that can serve as a reference for policymakers, science education and learning actors, and the general public in responding to science learning during and after a pandemic. In fact,

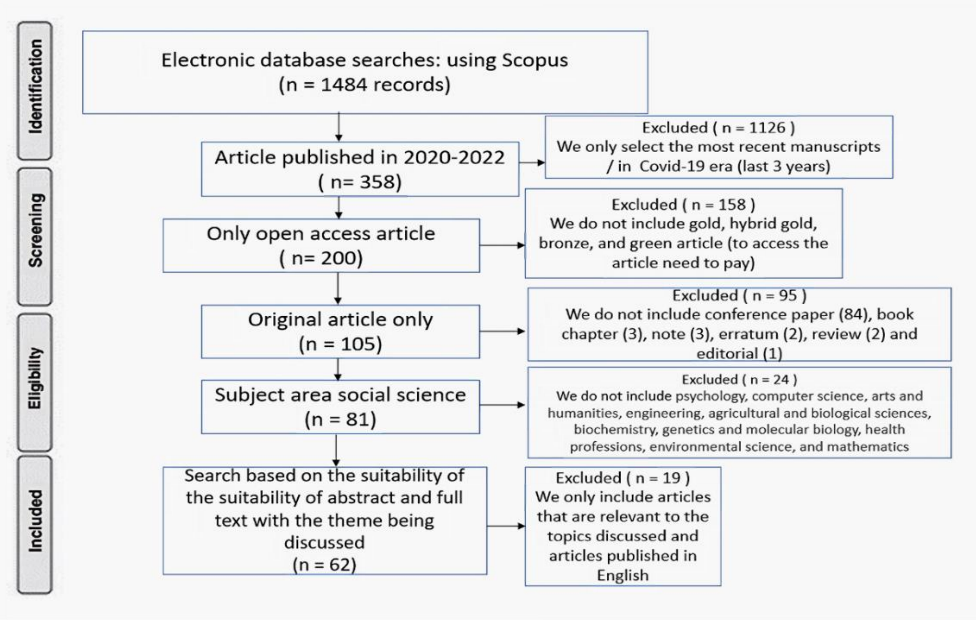

Figure 1. SLR flow diagram (PRISMA flow diagram for SLR detailing database searches, number of abstracts screened, & full texts retrieved) (Result of PRISMA process)

this can be taken into consideration when dealing with the next pandemic, which will, of course, have an impact on the world of education in general and science learning in particular.

METHOD

Research Framework

This review was an SLR in which it was an identification, evaluation and analysis technique of various existing and relevant information in the literature/references to answer research questions/problems and analyze them in depth (Snyder, 2019; Xiao & Watson, 2019). SLR "is helpful to summarize the latest knowledge on a particular topic with a systematic and transparent method of answering research questions" (Husamah et al., 2022b, 2022c, 2022a, 2022d; Kurniati et al., 2022).

Research Question

Determination of research question was used to define the scope to develop a clear focus for the study. This research questions were developed in response to the needs of the chosen topic, namely:

1. **RQ1:** How are the publication trends in Scopus-indexed journals related to the theme of "science learning"?
2. **RQ2:** What are perspectives of science learning transformation during COVID-19 pandemic?

Search Article and Inclusion Criteria

The researchers used "science learning" keyword in the search menu of Scopus database. The obtained data were storage in the form of *CSV and *RIS; later, the data were synchronized into reference manager (Mendeley). VOS-viewer software was used to visualize the data so that the information presented were more communicative, interesting, and clearer. The search histories on Scopus were, as follows: "TITLE ("science learning") AND (LIMIT TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT TO (PUBYEAR, 2020)) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English"))". The researchers found 1,484 articles using these search terms and patterns. The researchers used preferred reporting items for systematic reviews and meta-analysis (PRISMA) model to conduct an inclusion and exclusion. This model referred to Gallagher et al. (2016) and it was also used by Husamah et al. (2022). The following crucial points became the basis of inclusion criteria that used in this SLR, namely

(1) articles published in January 2020 to September 2022 (during COVID-19 pandemic),

(2) only open access articles,

(3) publications include original research articles,

(4) the subject area of the article is social sciences, and

(5) articles published in English and only articles related to "science learning" research.

Figure 1 depicted the order of inclusion and exclusion that the researchers used.

According to **Figure 1**, it was known that the researchers found 1,484 articles in the initial search. Subsequently, the researchers only took out the articles that published in 2020 to 2022. There were 358 articles

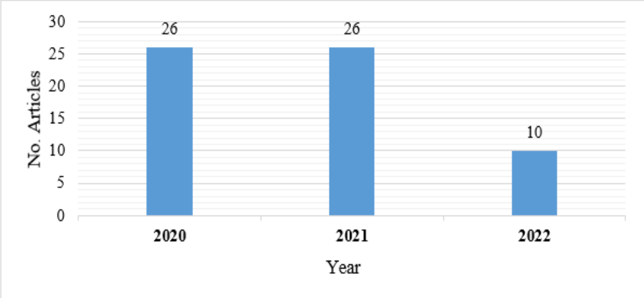

Figure 2. Distribution year of article (Source: Authors' own elaboration)

that met the criteria, resulting in the exclusion of 1,126 articles.

Furthermore, the researchers used open access article criteria. There were 200 articles that met the criteria, resulting in the exclusion of 158 articles. The researchers only used research article/original articles and there are 105 articles that meet the criteria using these criteria. There were 95 articles that were not included. Thereafter, the researchers used inclusion criteria in the field of science or subject area of "social science".

There were 81 articles that met the criteria, resulting in the exclusion of 24 articles. Subjects such as psychology, computer science, arts and humanities, engineering, agricultural and biological sciences, biochemistry, genetics and molecular biology, health professions, environmental science, and mathematics are declined by the researchers. In the final phase, the researchers re-examined the existing articles to ensure that the articles were consistent with the themes discussed, ensured the full texts were accessible, and the articles were published in English. Departing from the circumstances, the researchers found 62 articles that were corresponding or met the criteria, resulting in the exclusion of 19 articles.

RESULTS

Publication Trend of Science Learning Theme

Distribution year

Distribution year shows the number of articles published annually during COVID-19 pandemic, from 2020 to 2022. **Figure 2** represents the annual number of articles published from 2020 to 2022.

According to **Figure 2**, the highest number of publications on science learning themes occurred in 2020 and 2021, namely 26 articles, which corresponded to the beginning and peak of COVID-19 pandemic. Only 10 articles were discovered in 2022. As a result, there has been a downward trend in research on science learning over the last year. However, given that this data search was conducted in early October 2022, it is very possible that the science learning theme will grow. The number of science learning theme articles published and recorded in the Scopus database in October to December 2022 is very likely to increase.

Research types/methods

The trend of types of research related to "science learning" themes is presented in **Table 1**.

A study on science learning is more dominant to be conducted by using a quantitative approach (38 articles). There are also several qualitative studies, with a total of 20 articles. This proves that the issue of science learning can be approached using both quantitative and qualitative approaches. As a result, some researchers are interested in employing the mix-method (two articles). Another intriguing trend is the approach to science learning through case studies.

Table 1. Types of research on science learning themes

No	Type of research	Amount	References
1	Quantitative	38	Atmojo et al. (2020), Brookes et al. (2021), Chand et al. (2021), Chang et al. (2021), Darmawan et al. (2020), de Jong et al. (2021), Gandomkar et al. (2020), Gerard et al. (2022), Gilligan et al. (2020), Gray et al. (2021), Heinimäki et al. (2021), Herianto and Wilujeng (2021), Herodotou et al. (2022), Hugerat et al. (2020), Iiskala et al. (2021), Inkinen et al. (2020), Janprasert et al. (2020), Jeno et al. (2020), Jeong et al. (2021), Kim (2020), Koretsky et al. (2021), Kurniawan et al. (2022), Lee et al. (2021), Lundgren et al. (2022), Membiela et al. (2022), Nida et al. (2021), Nurhayati et al. (2022), Nusantari et al. (2020), Pande et al. (2021), Shana and Alwaely (2021), Skarstein and Ugelstad (2020), Studhalter et al. (2021), Sulistioning et al. (2020), Telenius et al. (2020), Tisza et al. (2020), Wang et al. (2020), Yakob et al. (2021), and Zorlu and Zorlu (2021)
2	Qualitative	20	Acharya et al. (2022), Archer et al. (2021), Barton et al. (2021), Chen et al. (2020), Christidou et al. (2022), Dawson et al. (2020), Durall et al. (2021), Gouvea (2021), Heinimäki et al. (2020), Hite (2022), Kervinen et al. (2020), Marshall and Conana (2021), Martins-Loução et al. (2020), Opere (2021), Outhwaite et al. (2022), Pierson et al. (2021), Rahmawati et al. (2020), Roberts (2021), Siry and Gorges (2020), and Zidny et al. (2021)
3	Mix-method	2	Bae and Lai (2020) and Hanif (2020)
4	Case study	2	Campbell and Speldewinde (2020) and Ryane and El Faddouli (2020)

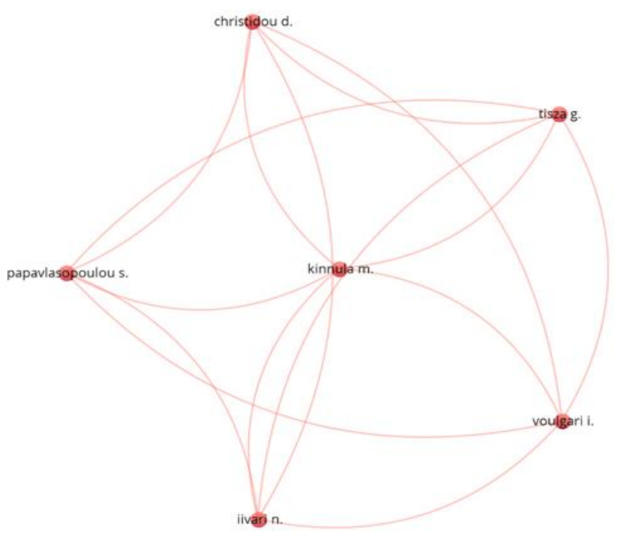

Figure 3. Dominant author and the relationship between authors in the theme of action competence (Source: Authors' own elaboration using VOSviewer software)

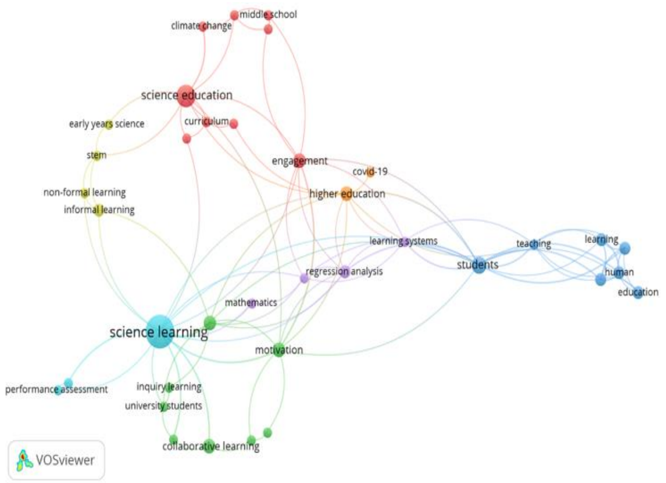

Figure 4. VOS-viewer display for type of analysis "co-occurrence→keywords" (Source: Authors' own elaboration using VOSviewer software)

Author and keywords

According to **Figure 3**, the most references are D. Christidou, G. Tisza, S. Papavlasopoulou, N. Iivari, I. Voulgari, and M. Kinnula. **Figure 3** also depicts the VOSViewer output, which includes the linking name and author, M. Kinnula. These names can be said to be interrelated, collaborating, or quoting, with M. Kinnula as the main reference. M. Kinnula is the author who has received the most attention in the study of science learning. M. Kinnula is a researcher in the field of science learning who is frequently cited by other researchers.

Figure 4 presents the keywords trend that often used by the authors in writing a science learning theme. Based on **Figure 4**, there are two main keywords that the most frequently occurring and interrelated, namely science learning and science education. The keyword of science learning is associated with performance assessment, inquiry learning, collaborative learning, and motivation. The theme of science learning is interesting since it is related to university students and higher education. Meanwhile, science education is related to curriculum and STEM. It is also important to note that the science education theme is related to climate change (part of the theme in environmental education).

Table 2. Author's nationality & continental on science learning themes

No	Country	Continent	Amount
1	the USA	America	**18**
2	Indonesia	Asia	**16**
3	Finland	Europe	**11**
4	the UK	Europe	**8**
5	Australia	Australia-Oceania	**6**
6	Germany	Europe	5
7	Spain	Europe	5
8	Norway	Europe	4
9	Taiwan	Asia	4
10	Ireland	Europe	3
11	Netherlands	Europe	3
12	Canada	America	2
13	Estonia	Europe	2
14	Malta	Europe	2
15	Portugal	Europe	2
16	South Africa	Africa	2
17	Switzerland	Europe	2
18	Turkey	Europe	2
19	Belgium	Europe	1
20	Brazil	America	1
21	China	Asia	1
22	Cyprus	Europe	1
23	Denmark	Europe	1
24	France	Europe	1
25	Greece	Europe	1
26	India	Asia	1
27	Iran	Asia	1
28	Israel	Europe	1
29	Kenya	Africa	1
30	Luxembourg	Europe	1
31	Morocco	Africa	1
32	Nepal	Asia	1
33	New Zealand	Australia-Oceania	1
34	South Korea	Asia	1
35	Thailand	Asia	1
36	United Arab Emirates	Asia	1

Author's nationality and international collaboration

The trend of author's nationality of research related to "science learning" themes are presented in **Table 2**. According to **Table 2**, there are 36 countries where the author comes from. If expressed as a percentage, the estimate is 18.65% of the world's total 193 countries. The five countries with the most publications on science learning themes are Indonesia (19 articles), the USA (18 articles), Finland (11 articles), the UK (eight articles), and Australia (six articles). Based on continents, Europe has the most authors who publish on science learning

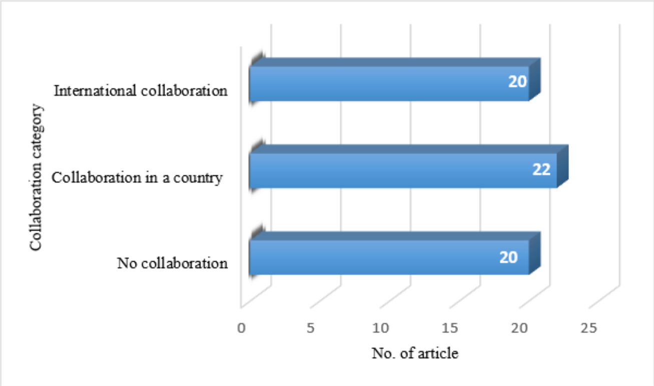

Figure 5. Author collaboration in writing articles (Source: Authors' own elaboration)

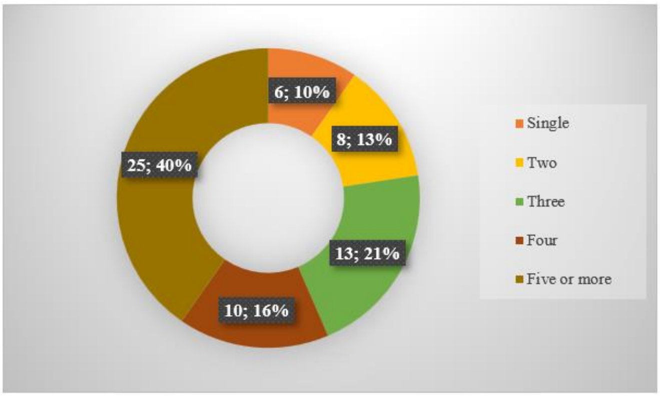

Figure 6. Distribution of scientist collaboration (Source: Authors' own elaboration)

Table 3. Funding sponsor science learning themes

No	Funding sponsor	Amount
1	National Science Foundation	11
2	Australian Research Council	4
3	European Commission	4
4	Horizon 2020 Framework Program	4
5	Academy of Finland	3
6	Ministry of Science and Technology, Taiwan	3
7	Welcome Trust	3
8	Department of Education and Training	2
9	Economic and Social Research Council	2
10	Islamic Development Bank	2
11	National Taiwan Normal University	2
12	Research Executive Agency	2
13	Suomen Akatemia [Academy of Finland]	2
14-62	There are 49 funding sponsors, each of which funds one research/article	

(48.70%) and followed by Asia at 26.96% and America at 18.26%.

Meantime, Australia-Oceania has a percentage of 6.09% and Africa has a percentage of 2.61%. The fact that articles about science learning during a pandemic were written by authors from all continents is intriguing, demonstrating the urgency of this theme, which deserves global attention.

Figure 5 indicates a collaboration in the article publication conducted by the authors, both cross-country collaboration, collaboration between universities within one country, and those that do not collaborate. Meanwhile, **Figure 6** is an illustration about distribution of scientist collaboration.

According to **Figure 5**, there are more articles published with collaboration status in one country (as many as 22 articles, or 35.48%). In fact, if we combine international collaboration (20 articles or 32.26%) and collaboration within a country, we can assume that the majority of the articles (42 articles or 67.74%) are written and published using a collaboration system. If we examine the 62 articles discovered (shown in **Figure 6**), we can conclude that articles written independently are uncommon (single author). Despite the fact that the articles are only written by authors from one university, it appears that they collaborate across disciplines by joining one research institute (research unit) at the university. Only six articles (10%) have been written independently/by a single author.

Funding sponsor

The trend of funding sponsor of research related to "science learning" themes are presented in **Table 3**. According to **Table 3**, there are 69 organizations or institutions around the world that fund research and publications about science learning. The National Science Foundation is the institution that provides the most funding. Several other organizations/institutions support each of the four studies/publications, namely Australian Research Council, European Commission, European Commission, and Horizon 2020 Framework Program. There are three other organizations or institutions, which fund two-three research or publications, and there are six organizations or institutions, which fund each research or publication.

Table 3 also presents that there are 49 funding sponsors in which each institution funds one research or article. It can be stated that most of the publications have complied with one of the ethics in publication, which is

Table 4. Important information for each article

No	Contribution of each reference	CWT	TT
1	Urgency of science learning partnerships (Outhwaite et al., 2022), science initiative (Gray et al., 2021), collaborative science (Heinimäki et al., 2020, 2021; Iiskala et al., 2021) to encourage availability of multimodality & new materialism in science learning (Marshall & Conana, 2021)	Need for science learning partnerships & initiatives & collaboration in encouraging new materialism in science learning	Philosophical basic transformation before learning
2	Implementation of science, particularly for children, can also be conducted informally or non-formally (Archer et al., 2021; Durall et al., 2021; Tisza et al., 2020); for instance, by using 'bush kinder' approach (Campbell & Speldewinde, 2020), follow leader technique (Roberts, 2021) & teacher talk (Studhalter et al., 2021), & need to see aspect of disruptive moments (Barton et al., 2021). In particular, social media can be used for informal science learning (Lundgren et al., 2022). Obstacles & challenges also need to be identified (Christidou et al., 2022)	Forms of implementing science learning: formal, informal, & non-formal	
3	Integrated urgency (Suraiya et al., 2020) & science learning spaces need to reduce social/gender inequality (Dawson et al., 2020), social positioning (Brookes et al., 2021), ethnopedagogy (Rahmawati et al., 2020), environmentally-based (Nusantari et al., 2020), climate change awareness (Jeong et al., 2021), indigenous science (Zidny et al., 2021), socio-scientific issues-based (Nida, Mustikasari, et al., 2021), life-based experiential learning (Acharya et al., 2022), religion & culture on student attitudes (Kurniawan et al., 2022), & should concern on political issues/identities (Gouvea, 2021)	Gender equality, local wisdom, life-based, socio-scientific, political issues/identities, religion, & even climate change must be addressed in science learning.	
4	Urgency of constructivist learning environment (Chand et al., 2021), inquiry-based (Martins-Loução et al., 2020) & digital inquiry-based (de Jong et al., 2021)	Constructivist theories can be applied to science learning.	Transformation in process of science learning
5	Urgency of didactic games in teaching science for young learners is needed (Hugerat et al., 2020) & need of daily exercise (Gilligan et al., 2020) or even everyday experiences (Kervinen et al., 2020).	Practice-based science learning & fun	
6	Student meaning making & interest maintenance (Siry & Gorges, 2020; Wang et al., 2020); need of self-regulated learning & self-awareness during COVID-19 (Atmojo et al., 2020); & 21st century skills & self-efficacy (Zorlu & Zorlu, 2021), students' emotional level & friendship in science learning (Kim, 2020), spatial abilities (Chen et al., 2020), student engagement (Bae & Lai, 2020; Lee et al., 2021; Pierson et al., 2021), students' situational engagement (Inkinen et al., 2020), & productive disciplinary engagement (Koretsky et al., 2021; Membiela et al., 2022).	Science learning needs to pay attention to students' self (self-regulated, self-awareness, self-efficacy, & student engagement)	
7	Fun in learning, interest in learning time, social implications, scientific normality for science learning (Sulistioning et al., 2020), & outdoor learning (Skarstein & Ugelstad, 2020)	Learning should not only be in classroom	
8	Necessity of media literacy (Anwar et al., 2020) that is embodied in the form of science learning framework online (Opere, 2021), online community (Herodotou et al., 2022), flipped classroom (Shana & Alwaely, 2021), open educational resources (Gerard et al., 2022), use of multimedia (Herianto & Wilujeng, 2021), virtual reality	Science learning media must be technologically advanced	
9	understanding (Hite, 2022), virtual science learning (Telenius et al., 2020), using Edmodo (Ryane & El Faddouli, 2020), animated videos (Nurhayati et al., 2022), motion graphic animation videos (Hanif, 2020), mobile science learning (Chang et al., 2021; Jeno et al., 2020)., VR simulations (Pande et al., 2021)		
10	Urgency of cognitive assessment techniques (Darmawan et al., 2020), multiple self-regulated learning measures (Gandomkar et al., 2020), & performance assessment (Yakob et al., 2021).	Transformation in assessment	Transformation in learning assessment & evaluation
11	Urgency severity & leniency effects on alignment evaluation (Janprasert et al., 2020)	Necessity to consider evaluation system used	

Note. CWT: Connection with transformation & TT: Type of transformation

to clearly state the names of organizations or institutions that fund their research and publications.

Perspectives of Science Learning

We have reviewed 62 articles in order to develop perspectives for transforming science learning during COVID-19 pandemic. According to **Table 4**, the results can formulate 11 things related to the transformation of science during a pandemic. Eleven formulations can be classified into three types of transformation: philosophical basic transformation before learning, transformation in science learning process, and transformation in learning assessment and evaluation.

DISCUSSION

Publication Trend of Science Learning Theme

Distribution year

There is a downward trend in research about science learning on one last year. But numbers of publication in 2020 and 2021 are stable/fixed; there are 26 articles. Particularly in 2022, there is also a downward trend, yet, it can be said that the data are not final since the publication process is still ongoing, and it is very likely that the number of science learning publications in 2022 will increase because many articles have not yet been included in the Scopus database. Given that 2020 was the start of a pandemic and 2021 is the peak of a pandemic, large number of publications on science learning themes in 2020 is very reasonable. The world of education, including science education, is attempting to adapt to COVID-19 pandemic's problems. Science learning innovations and studies have sprung up in an attempt to survive COVID-19 crisis/pandemic (Erduran, 2020b; Schleicher, 2020). Science learning should be flexible so it can survive and keep going (Anderton et al., 2021).

Research types/methods

A study on science learning is more dominant to be carried out by using quantitative approach. There are also a lot of qualitative studies. Quantitative and qualitative research paradigms can be used to approach science learning and science education. This type of research has an urgency to introduce educators and researchers to the most recent articles of interest in the context of science learning (Eddy, 2019). In a broader context, science education is a multi-faceted effort, including creating learning materials, preparing teachers, and conducting research on science learning (Porfolio et al., 2022). A study on science education is an effort to look for principal articulation and practice in which it is used by the researchers to make a valid claim about the world and their criticism about the claim. This type of research is significant since it brings these principles and practices to the attention of the scientific community, allowing them to be considered, debated, assessed, and accepted, rejected, or reframed. What matters is that these principles and practices continue to evolve in ways that allow our knowledge in the field to evolve (Nichols & Nielsen, 2022).

The studies can reveal major transformations in learning research and provide evidence of how science can inform innovation in regulatory design, policy, practice, and research to improve learners' lifelines, opportunities, and prosperity. It will undoubtedly be an invaluable and one-of-a-kind resource for understanding the basis and status of new knowledge, as well as a roadmap for progress that will frame advances in science learning (Cantor & Osher, 2021). It aims to improve students' and researchers' knowledge and skills so that they can conduct a variety of quantitative and qualitative studies aimed at improving science teaching and learning in educational institutions and other educational settings (Sherman & Webb, 2005; Schulze, 2003).

Issues in science learning can be approached thru a quantitative and even qualitative or a combination of the two (mix-method). In this regard, the purpose of science learning research is to discover the truth through a combination of reasoning and experience. A different research approach, based on the collection and analysis of data used at a specific time, is required to find the right learning method. Although qualitative and quantitative research methods are on different scales, they both aim to identify educational problems in different approaches (Daniel, 2016). The combination of the two methods will provide an illustration of implication for school and class practices for emerging consensus about science learning and science development, which is outlined in current research synthesis (Darling-Hammond et al., 2020).

In other cases, science learning trend can be approached using a development. Development research in science education is required to develop innovative and up to date learning material and pedagogical model and its implementation as well, teacher professional development and research on teaching and science learning as a long-term ongoing activity that informs and guides every researcher through an interactive spiral cycle. Those activities are arranged, guided, and tested using highest academic standard, use and improve existing theoretical and methodological frameworks, or develop new paradigms and findings, in order to advance science learning as an academic discipline and improve the quality and effectiveness of science learning at the educational institution level (Porfolio et al., 2022).

Science learning can be approached by using a case study. A case study is a historical context with a single unifying idea that is designed in accordance with guidelines for writing large context problems. An international team of historians, scientists, and teachers must conduct case studies that are modular, testable, and push science beyond textbooks (so that they can fit into or be part of the curriculum) (Stinner et al., 2003). A case study of science learning in undergraduate programs began decades ago. Nowadays, thousands of teachers used this method and there is main web site to post hundreds of cases study and teaching records across all STEM disciplines, particularly biology. This method is chosen since there is strong evidence to suggest that it is superior to other approaches (Herreid, 2011). A case study can be utilized in any discipline, including science; when the teachers want the students to explore what they have learned applies to real-world situations. Cases, on the other hand, can range from simple to complex (Dunne & Brooks, 2004).

Author and keywords

Marianne Kinnula is an author who is a "central figure" in science learning studies during 2020-2022. The articles she has published are widely cited by other authors in this field. Marianne Kinnula is an Associate Professor at Finland's University of Oulu. According to a Google Scholar search, he published 43 articles in scientific journals and proceedings between 2020 and 2022. He can be the first author, the corresponding author, or a member of the authors' group. According to the Scopus database, he has published 81 papers, been cited 657 times, and has an h-index of 15. There are 32 articles generated by Marianne Kinnula during pandemic. There are six publications in which he serves as lead author (Kinnula et al., 2020a, 2020b, 2021, 2022; Kinnula & Iivari, 2021). Marianne Kinnula colors science learning publications all over the world since he has so many publications.

According to the data, the keywords science learning and science education are frequently used in publications. Science learning is associated with performance assessment, inquiry learning, collaborative learning, and motivation. Even decades ago, some experts linked science learning and performance assessment (Kind, 1999; Okey, 1995; Shavelson et al., 1991). During pandemic, science learning is also still a concern by the researchers (Yakob et al., 2021). Moreover, science learning is also related to inquiry learning. For instance, researchers postulate the importance of applying inquiry learning methods to develop students' generic science skills (Hastuti et al., 2018; Razali et al., 2020; Widowati et al., 2017).

During pandemic, the researchers emphasize the importance of linking generic science skills with inquiry learning (Khoiri et al., 2020) and even the linking between Inquiry-based learning and e-learning to serve the students' science learning processes with a high level and low achievers (Sotiriou et al., 2020). Meanwhile, the science learning research is also related to collaborative learning. During pandemic era, the researchers connects the science learning and collaborative learning particularly in the online learning context (McCollum, 2020), small-group discussions on student-teacher (Williams & Svensson, 2021), and emotion regulation (Järvenoja et al., 2020). On the other hands, science learning is also related to motivation theme. Järvenoja et al (2020) try to analyze an adaptive motivation in the science classroom. Fortus and Touitou (2021) focus their review on changes to students' motivation to learn science. Membiela et al. (2022) examine the motivation for science learning as an antecedent of emotions and engagement. In addition, Rahmouni and Aleid (2020) focus on the teachers' practices and children's motivation towards science learning and Chai et al. (2021) are further highlighting the intrinsic motivation and sophisticated epistemic beliefs.

Science learning theme is also related to university student and higher education. This is in line with several viewpoints of experts that science learning in college is suggested to use the most productive way in learning and how it relates to the constructivist learning process. Science learning in college should be based on active learning, and ways for student learning to run in an effective atmosphere (Bao & Koenig, 2019; Cavanagh et al., 2016; Hassel & Ridout, 2018; Leonard, 2002). It is necessary to implement evidence-based teaching practices at all levels of higher education by providing effective incentives and evaluations (Miller, 2015). In practical level, blended learning should be implemented during pandemic to support the science learning (Finlay et al., 2022; Verde & Valero, 2021). Project-based learning can also be implemented consistently (Guo et al., 2020).

In the meantime, science education is linked to curriculum and STEM. The curriculum of science education should notice more authentic science curriculum (Braund & Reiss, 2006). The science curriculum is an important guideline in realizing effective science learning (Baptista & Molina-Andrade, 2021; Penuel et al., 2022; Shaji & Indoshi, 2008; Soysal, 2022). The teachers need to be innovative in creating different learning strategy so that it can engage students in subjects they find complex and relevant. Thus, curriculum design must be oriented toward making science subjects more enjoyable and meaningful for students (Al-Mutawah et al., 2022).

Science education is related to STEM. The term STEM is used to emphasize an understanding of the integrated disciplines of science, technology, engineering, and mathematics. STEM is a paradigm that creates inter-disciplinary learning and provides achievement results of science, mathematics, engineering, and technology while doing so (Nugroho et al., 2019). For most, it means only science and mathematics, even though the products of technology and engineering have so greatly influenced everyday life. A true STEM education should increase students' understanding of how things work and improve their use of technologies (Bybee, 2010). If science is to be taught to achieve the goals outlined in the majority of today's STEM reform efforts, students must be more centrally involved than mere "receivers" of information. They must be the "doers" in the real science (Yager, 2015).

It's also important to note that the science education theme is related to climate change (part of the theme in environmental education). Climate change should become a major concern for science educators. Science education must play a significant role in society's response to global climate change (Meilinda et al., 2017; Park et al., 2020; Sharma, 2012). If necessary, science education can be used to solve problems caused by climate change (Jurek et al., 2022; Nwona, 2013). The importance of learning and action of climate change–specially place-based, participatory, and action-focused pedagogy–in science education needs to be strengthened (Trott & Weinberg, 2020). Climate change has clear connection with the welfare of society, and it will be a definite offense to ignore it in our educational programs for years to come. We should prepare the students to have science and to understand the phenomenon behind the change. An adaptation on the proper way to teach science using new theme and interdisciplinary about climate change should be prepared (The Pontifical Academy of Sciences, 2022). The end of all this is the need for the implementation of environmental education and the urgency of environmental literacy (Amalia et al., 2021; Angreani et al., 2022; Hermawan et al., 2022; Marpaung et al., 2021; Mayarni & Nopiyanti, 2021; Nada et al., 2021; Nainggolan et al., 2021; Solheri et al., 2022).

Author's nationality and international collaboration

There are 36 countries of origin for authors who publish articles, with the majority coming from Europe, though Indonesia has the most publications (Asia). This is in line with Agency et al. (2012) that European Commission has verified the features of science teaching organizations across Europe and has mapped out the policies and strategies implemented to improve teaching and promote science learning in schools. Particularly, they have received available support for the teachers to assist them in changing the students' behavior and to increase the students' interest in science. Especially in Europe, according to Osborne and Dillon (2008), in recent decades, there has been a growing consensus that science should be a compulsory school subject. While there is agreement that science education is important for all school students, there is little debate about its nature and structure. In line with the statement, according to Jorde and Dillon, (2012), in Europe, it becomes clear that, as science educators, we must believe that science content is broad and must be the same wherever it is taught around the world. However, cultural diversity means that science curricula are delivered in a variety of ways, resulting in very different learning outcomes. Some European countries differentiate early, while others do not.

It appears that the theme of science learning is particularly important for researchers in Indonesia. According to Faisal and Martin (2019), currently, initiatives aimed at developing a national curriculum, improving teacher preparation and professional development, and promoting educational research are driving changes in the education system that affect science learning in Indonesia. The current state of Indonesia's education system indicates a growing understanding of the specific challenges, as well as progress in science learning in Indonesia. In particular, the development of a national science curriculum and science textbooks is currently underway in Indonesia. This is followed by a discussion of some of the challenge's teachers face when attempting to implement a standardized curriculum in various types of schools, with diverse students, and in highly varied learning environments. Indonesia, in particular, is undergoing a process of scientific learning improvement, and we can expect to see continued development and improvement in Indonesian science learning research, science teacher education, and Indonesian student learning and achievement in science.

Articles on science are written by the authors from all continents in which it shows that science learning become the spotlight of the world or become a global issue. Education and scientific learning are quickly becoming important components of globalization (Deboer, 2011) and affect the country's development (Kola, 2013). This is reasonable considering that science is humanity's common heritage. It is the only human treasure that can offer a possible cure for overcoming inequality and achieving an acceptable quality of life and goals for the vast majority of the world's people (Kaptan & Timurlenk, 2012).

The global world is filled with anger, fear, misinformation, distrust and discouragement (Reis, 2021), especially during a pandemic. Global society should be modern science-and technology-based societies (Krell et al., 2022) and has strong scientific reasoning (Bicak et al., 2021; Hilfert-Rüppell et al., 2021; Khan & Krell, 2021; Mahler et al., 2021; Meister & Upmeier Zu Belzen, 2021; Rost & Knuuttila, 2022; Schellinger et al., 2021). COVID-19 pandemic has provided on disclosing the fact that most of the public science education and learning. Three more ambitious and significant goals for science learning at all levels are, as follows:

(1) to provide all people with a skill in identifying scientific problems: using logic, experiment, and evidence,

(2) to provide understanding for all people about the scientific procedure–and why they should trust the consensus judgments of science on science issues, and

(3) to equip all people with the habit of solving their everyday problems the way scientists do, using logic, experimentation, and evidence.

All such efforts are urgent and can culminate in implementation at the university level (Alberts, 2022). Recently, there has even been a call from various professional communities to engage in interdisciplinary collaboration and to reflect across disciplinary boundaries in order to form new syntheses that may benefit science learning across the spectrum of policy, research, and practice (Erduran, 2020a).

It has been discovered that more articles are published as a result of collaboration between universities within one country and between countries. Articles are rarely written by a single author. A good scientific article should be written collaboratively, both within and across fields of study (Bellotti et al., 2016; Bennett & Gadlin, 2012; Frassl et al., 2018). Collaboration carried out by scientists in a research and publication is very crucial, especially to solve the complexity of theme and research problems, which need an integration of knowledge from various disciplines (Eberle et al., 2021). Scientific publications are the building blocks of discovery and collaboration. This pattern encourages greater legibility, comprehension, and confidence. It is a method of expressing multiple points of view in a more collaborative and diverse manner (Freeling et al., 2021). Collaborative research encourages group creativity that exceeds the creativity of any individual on the team, in the publication context will provide high impact since it is the result of interdisciplinary thinking (Uzzi et al., 2013). Therefore, publication encourages collaboratively the emerge of group creativity to maximize novelty and innovation since it has gone through the process of individual reflection and brainstorming during the script development process (Oliver et al., 2018).

Pragmatically, in fact, interdisciplinary research receives more funding than research in a single field (Bellotti et al., 2016). As a result of this trend, more and more research are being conducted in large groups, increasing the likelihood that articles will be written by multiple authors from various institutions, disciplines, and cultural backgrounds. While it is important to recognize that collaborative writing with multiple authors presents additional challenges, such as author engagement, fair crediting, diversity of work styles, and communication clarity (Frassl et al., 2018). Other challenges include, for example, differences in theoretical and methodological approaches across the lines of work completed by the team (Peffer & Renken, 2016).

Funding sponsor

There are 69 institutions which fund the research and publication of science learning. The research funding has decided to be an important sources in science reward system (Zhao et al., 2018). A research and publication funding is a grant obtained through a competitive process to conduct research and scientific publications in general (Neema & Chandrashekar, 2021). The relationship between grants and research productivity has not been well described (Saygitov, 2018), although it is believed that research funding has a direct impact on the behavior of academics (Vaughan, 2008). Yet, we believe that research and publication funding will have an impact on the quality of research and publications conducted (Ebadi & Schiffauerova, 2015; Győrffy et al., 2020). This is in line with the context findings of a study in Finnish academics (Mathies et al., 2020). Case analysis in Swiss National Science Foundation also indicates the researchers who are funded to improve the quantity and the funding also encourages the encourage dissemination and quality (Heyard & Hottenrott, 2021). Even interesting findings are conveyed by Wang and Shapira (2015) that publication from a research funded by a grant indicates higher impact in terms of journal ranking and number of citations than non-grant-sponsored research. As well as the findings stated by Zhao et al. (2018) that funding has an impact on the usage and quotation, and funded papers attract more uses, but vary across disciplines. There is a positive correlation between usage and funding.

Most of publications have met one of ethics in publication; clearly stating the name of the organizations/institutions that fund their research and publication. Stating the organizations/institutions, which provide funding is important to indicate the honesty and openness of researchers. However, funding institutions emerge as clear and influential actors in scientific communication systems, influencing the type of knowledge produced and making important decisions about the research supported (Álvarez-Bornstein & Montesi, 2020). Nevertheless, it must be remembered that the main thing is the independence of researchers since we need to build a system that emphasizes the quality control of research objectives (Hagve, 2020).

Transformation Form of Science Learning

The analysis results (as shown in **Table 4**) indicate that there are three crucial points in the formulation of science learning transformation during COVID-19 pandemic. The first point is philosophical basic transformation before learning. This formulation is based on the notion that

(1) there is a need for science learning partnerships and science initiatives to encourage new materialism in science learning,

(2) there are three types of science learning implementation: formal, informal, and non-formal, and

(3) science learning must be relevant to people's lives: gender equality, local wisdom, life-based, socio-scientific, political issues/identities, religion, and even climate change.

Science learning must be strong philosophically (Robinson, 1969). Most scientists and science students are skeptical of philosophical foundations, according to a recent trend. Thus, the skepticism of scientists and students toward this philosophical foundation must be overcome. (Fjelland, 2022). In fact, several specific philosophical perspectives on science are discovered in the field. In fact, an accurate understanding of philosophy of science will be critical in implementation settings, such as experimental studies, practical changes in philosophy of science, epistemological development, empirical changes in philosophy of technology, and new methods for interpreting moral relevance (Moreno & Vinck, 2021).

On a practical level, as it can be found in the articles published on 2020 to 2022, it is emphasized the importance of science learning partnerships and science initiative to encourage new materialism in science learning. Science learning partnerships and science initiative leads to the certainty of the need for collaboration as a form of professional work during a pandemic (Outhwaite et al., 2022). In science, collaboration encompasses sharing information, ideas, and data, as well as cooperating on research projects. Collaboration allows scientists to combine knowledge and resources in an interdisciplinary manner to generate new ideas, produce better results, and work faster than would otherwise be possible. (Millis, 2016; Vamos et al., 2020; Wilson, 2022).

Additionally, a new materialist approach known as "inclusive materialism" is required since it is considered to have a potency in framing a more socially equitable pedagogy. New materialism perspective can contribute to reconfigure pedagogical practice in the curriculum program and science learning (Marshall & Conana, 2021).

Furthermore, it is emphasized that the form of implementation of science learning are formal, informal, and non-formal. Formal science learning is most likely something we are all familiar with. However, it is critical to recognize that science can be implemented both formally and informally in order to broaden its reach and utility (Archer et al., 2021; Durall et al., 2021; Tisza et al., 2020). Several examples of science implementations informally and non-formally during pandemic are by using 'bush kinder' approach (Campbell & Speldewinde, 2020), follow the leader technique (Roberts, 2021), and teacher talk (Studhalter et al., 2021). However, science practitioners need to look at aspects of disruptive moments (Barton et al., 2021) and Obstacles and challenges are required to be identified (Christidou et al., 2022) in which it may occur in daily practices. Particularly, it has become a necessity at this time; social media can be used as informal science learning (Lundgren et al., 2022). In real practice in China, for instance, it is found that

(1) science learning that utilize the social media can empower the students with timely learning opportunities,

(2) daily tweets on social events or hot topics that emerge or come off will provide a "bite" about interesting knowledge in which it often leads to additional reading and related resources, and

(3) the integration of social media encourage broad public engagement in the science learning and various knowledges (Zhang & Gao, 2014).

Science learning should be related to community life. Several issues that can be linked are gender equality (Dawson et al., 2020), social positioning (Brookes et al., 2021), ethno-pedagogy (Rahmawati et al., 2020), indigenous science (Zidny et al., 2021) socio-scientific issues-based (Nida, Mustikasari, et al., 2021), life-based experiential learning (Acharya et al., 2022), religion and culture (Kurniawan et al., 2022), political issues/identities (Gouvea, 2021), environmental (Nusantari et al., 2020), and climate change awareness (Jeong et al., 2021). We need science that is relevant with current condition and even for future condition (Kaptan & Timurlenk, 2012). Science should "accompany" the modern society in overcoming complex scientific issues (Nida et al., 2021). Those issues are varied in terms of the scope, clarity, and originality of the problem, the degree of collaboration required, the complexity, and the interpretative perspective required (Allchin, 2013). This includes how the scientific community generates scientific information, how the media repackages and distributes information, and how individuals discover and form opinions about that information (Howell & Brossard, 2021). There are many societal problems that science can address in the current context, one of the most pressing of which is environmental issues (Angreani et al., 2022; Hermawan et al., 2022; Husamah et al., 2022b; Rahardjanto et al., 2022).

Second, the transformation in the science learning process. This formulation is based on the notion that

(1) science learning can implement the constructivist theory as inquiry-based learning,

(2) practice-based science learning and fun,

(3) science learning needs to concern on the students' self (self-regulated, self-awareness, self-efficacy, and student engagement), and

(4) the learning should not only be in the classroom.

Constructivism is used to justify design, implementation, and evaluation (Forster, 1999), despite the fact that teaching practice and research activities are the most important (Suhendi & Purwarno, 2018). The constructivist theory of how individuals express science-related knowledge in professional interactions is emphasized for the acquisition, expression, and application of knowledge in practice (Thomas et al., 2014). Learning based on constructivist views and strategies in constructivist learning can encourage in-depth learning and practical applications in the context of the development of information technology (Sejzi & Aris, 2012).

Science learning must be practice-based and enjoyable. Students will be bored and will not achieve their learning objectives if science learning activities are not interesting or intellectually challenging. Yet, by implementing practical activities or stimulating discovery, the students can collaborate to develop their understanding skill and scientific literacy (Kim & Kim, 2021). Several authors understand that practice has important roles since it may be possible to support the improvement of quality in the learning processes (Matzembacher et al., 2019). Several types of practice in science learning that suggested by the experts are spaced practice, interleaving, retrieval practice, elaboration, concrete examples, and dual coding (Weinstein et al., 2018). Additionally, science learning should be fun. Fun learning is an important strategy to promote student engagement, inclusion, and holistic skills development beyond (Parker et al., 2022). Fun is the crucial element in learning. Hence, creating fun learning activities to facilitate the involvement of students in the learning processes and improve learning outcomes should be conducted by the teachers. Unfortunately, despite widespread interest, little systematic effort has been made to define and apply the fun aspect (Tisza & Markopoulos, 2021).

Science learning should notice on the students' self (self-regulated, self-awareness, self-efficacy, and student engagement). To be successful in learning during and after a pandemic, students must develop independent study skills in order to effectively manage their learning process (Higgins et al., 2021; Santoso et al., 2022). Furthermore, educators usually use the concept of self-awareness in order to describe one's ability to think about, talk about, and define feelings, thoughts, and/or actions. Presently, the term 'self-awareness' is used to describe an overall concept that includes many sub-concepts (Flavian, 2016; Jaakkola et al., 2022). Additionally, accurate investigation on self-efficacy of students can provide the basis for how to process and develop it in science learning (Hu et al., 2022; Ketelhut, 2007). On the other hands, the student engagement in science is related to students' motivation on science, enjoyment of science, and a future orientation towards science. The term of student engagement is used to framed a study that focuses on frequency of participation in the activities (Godec et al., 2018).

In different context, it is emphasized that learning should not only be in the classroom (but also outside the classroom). Integrating outdoor learning into indoor learning experience is excellent way to enrich students learning experiences (Koto & Susanta, 2019). Outdoor learning is increasingly seen as a means of promoting and fostering an emotional connection between students and the natural environment. This is an attempt to understand that in teaching science we must really consider the importance of imagination and creativity. They are essential for good science practice (Curtis, 2020; Education Scotland Foghlam Alba, 2009).

Third, transformation in the learning assessment and evaluation. This formulation is based on the notion that

(1) assessment transformation is important and

(2) need to consider evaluation system carried out.

Science learning assessment should adjust with the situation and life demands during pandemic. Various policies implemented by the government in various countries insist the schools to adapt, and the assessment used by the teachers should adjust with the policies (Martin et al., 2021; Sandvik et al., 2022). The teachers should be aware that they certainly will not be able to complete their curriculum and assessments in the normal way. Those who are unable to adjust will be anxious until they have clear indications of how their learning and assessment systems will be restored following a crisis. In this case, certainly there will be many students in COVID-19 group will be worried about suffering long-term losses, compared to those studying "normally", when they move to another level of study or enter the labor market (Daniel, 2020; DeCoito & Estaiteyeh, 2022). Anyway, in the global context, this condition will be experienced by millions of students affected by the pandemic (Montenegro-Rueda et al., 2021).

Therefore, in a wider context, transformation in considering the evaluation system conducted during pandemic should be noticed. Evaluation is important since many entities develop the information system during pandemic to conduct the education and improve the effectiveness and efficiency so that it can reach the learning objectives (Ngabiyanto et al., 2021; Rokhman et al., 2022). At this time, teachers and education providers must investigate how students evaluate online teaching, how frequently they participate in online learning compared to face-to-face learning, and, ultimately, which mode of learning (offline or online) they prefer after the pandemic is over (Szopinski & Bachnik, 2022).

CONCLUSION

This SLR provides interesting results. In the last year, there has been a downward trend in research on science learning. Nonetheless, the number of publications is stable/fixed in 2020 and 2021. The number of articles will also decrease, particularly in 2022. The researchers discover that most science learning research is conducted quantitatively, followed by qualitative research. Quantitative and qualitative research paradigms can be used to approach science learning and science education.

The researchers also discover that the author who is most in the spotlight in the study of science learning is Marianne Kinnula. Marianne Kinnula is one of researchers in science learning area that often used as reference for other researchers. Meanwhile, based on the data, science learning and science education keywords are the dominant keywords used in the publications. Science learning keywords is related to performance assessment, inquiry learning, collaborative learning, and motivation. The theme of science learning is also related to university student and higher education. Science education is related to curriculum and STEM. The interesting point is that science education theme is related to climate change as well (part of the theme in environmental education).

The researchers also elucidate that there are 36 countries of origin of the authors who published articles, dominantly from Europe, although the country with the most publications is Indonesia (Asia). It appears that the theme of science learning is particularly important for researchers in Indonesia. It has been discovered that more articles are published when universities collaborate both within and between countries. Articles are rarely written by a single author. The fact that there are 69 institutions globally that fund research and publications on science learning is encouraging. Ethically, it is obtained interesting information that the majority of publications have fulfilled one of the ethics in publication, which is to clearly state the names of organizations/institutions that fund their research and publications.

The researchers can formularize three crucial points about transformation of science learning during COVID-19 pandemic, namely

(1) philosophical basic transformation before learning,

(2) transformation in the science learning process, and

(3) transformation in the learning assessment and evaluation.

Those three perspectives of transformation are constructed from ten things that are formulated based on the references that the researchers have found and analyzed. The second and third perspectives from the transformation that we have formulated are interesting for further study, especially dealing with the dynamics of learning science during COVID-19 pandemic or post-pandemic COVID-19.

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