Bibliometric Investigation in Misconceptions and Conceptual Change Over Three Decades of Science Education

Mohd Zaidi Bin Amiruddin [ID]
Universitas Pendidikan Indonesia, INDONESIA

Achmad Samsudin[*] [ID]
Universitas Pendidikan Indonesia, INDONESIA

Andi Suhandi [ID]
Universitas Pendidikan Indonesia, INDONESIA

Bayram Coştu [ID]
Yıldız Technical University, TÜRKİYE

Abstract: This paper explores information related to misconceptions and conceptual change during the last thirty years 1992-2022 to be used as a preliminary study in science education. This study used bibliometric analysis with the help of the Scopus database. This paper used a bibliometric analysis study with the Scopus database and the help of MS Excel, VosViewer, and Rpackage software to visualize the data obtained. The results of this research found that Indonesian researchers have contributed the most in terms of the number of documents published in Australia and the United States. Additionally, research on these two topics has decreased since 2019 due to the Covid-19 pandemic. In addition, these findings present trends in the areas of misconceptions and conceptual change that can be used as baseline data for future research. Studies related to misconceptions will continue to develop because they cannot be separated from the inside of education, whether at any level of elementary school, middle school, or college. This is an opportunity that must be taken advantage of by institutions and policies in an effort to improve and create quality of education, teacher resources, and students.

Keywords: *Bibliometric, conceptual change, misconception, science education, trend research.*

Introduction

Globally, topics related to misconceptions and conceptual change continue to develop in various countries. This is proven through research conducted by researchers in this field based on the Scopus database with keywords such as misconceptions (28549 docs) and conceptual change (56355 docs). The topic of misconceptions and conceptual change is crucial to research at the educational level, especially in junior high, senior high, and college. Various concepts are studied in science, especially natural science, consisting of physics, chemistry, biology, astronomy, and geology. According to Broström (2017), and Shah (2019), the concepts studied often cause misunderstandings in the ongoing learning process. This becomes a problem that impacts learning new ideas related to the material. In this way, it is hoped that learning that contains essential concepts can be illustrated and made an analogy with real examples found in everyday life. The relationship pattern between conceptual change and misconceptions thoroughly using VosViewer is presented in Figure 1 as a visualization of the networking for the keywords (misconceptions AND conceptual AND change).

---

[*] **Corresponding author:**
Achmad Samsudin, Universitas Pendidikan Indonesia, Indonesia. ✉ achmadsamsudin@upi.edu

Figure 1. Network Visualization Misconceptions and Conceptual Change

Teachers have implemented various solutions to remediate student misconceptions, such as developing question instruments (Anam et al., 2019; Kaniawati et al., 2019; Kınık Topalsan & Bayram, 2019; Kiray & Simsek, 2021; Tumanggor et al., 2020) augmented reality (Altmeyer et al., 2020; Gnidovec et al., 2020; Sahin & Yilmaz, 2020; Thees et al., 2020; Turan & Atila, 2021; X. Zhou et al., 2020), teaching method (Fauth et al., 2019; Gómez-Carrasco et al., 2020; Moodley & Gaigher, 2019; Rasmitadila et al., 2020). In this case, these developments are only tools to make learning the correct concepts related to the studied material or conceptual change easier. Based on previous studies, state that some of the causes of misconceptions are mental lack of preparation (Ahonen et al., 2019; Peel et al., 2019; Potvin et al., 2020), lack of interest in the knowledge being studied (Prodjosantoso et al., 2019; Soeharto et al., 2019), conceptual errors conveyed by teachers (Fauth et al., 2019; Fuadiah et al., 2019; Mufit et al., 2019; Saputra et al., 2019), inappropriate learning resources (Leacock & Nesbit, 2007; K.-H. Yang & Lu, 2021; Yolanda, 2020), and material presented abstractly (Fadillah & Salirawati, 2018; Resbiantoro et al., 2022). Based on this, it is essential to understand the characteristics of the material and the student's delivery of the material to avoid misconceptions.

A wrong concept without improvement will become an obstacle for someone to understand other images in a complex way in the future. In line with research results from Fuadiah et al. (2019), Kahu and Nelson (2018), and Suprapto (2020), a negative impact will occur on students' understanding of new concepts when misconceptions arise. Misconceptions can also influence a person's thought patterns and behavior, resulting in less-than-optimal learning outcomes. Additionally, misconceptions have short-term and long-term impacts, becoming trending topics that must be resolved (Akour & Alenezi, 2022; Allen et al., 2022; Pekrun, 2022; K.-H. Yang & Chen, 2023).

This study will explore trends related to misconceptions and conceptual changes over the last thirty years. This paper provides updates regarding information and solutions that have been carried out, as well as predictions for future research. According to Donthu et al. (2021), D. Li, Opaza, et al. (2020), Sigala (2020), and Vrontis et al. (2021), it is urgent to know the development of research topics because it can provide an overview of future research opportunities. The Scopus database is the primary source of information used in research because it is an internationally reputable indexer. Several questions must be answered in this study as follows:

RQ1. What is the main information on the publication of misconceptions and conceptual change?

RQ2. What are the trends in publications on misconceptions and conceptual change?

RQ3. Which author contributed most to the topic of misconceptions and conceptual change?

RQ4. Which countries contributed most to misconceptions and conceptual change?

RQ5. What is the most relevant word on misconceptions and conceptual changes?

RQ6. What is the relationship between misconceptions and conceptual change in education?

Methodology

This study used bibliometric analysis with the help of the Scopus database. According to Akcan (2022), Schildkamp (2019), Siahaan et al. (2023), Yu and Li (2022), and Prahani et al. (2022), bibliometric analysis is a type of qualitative and quantitative analysis that can provide the latest information related to the topic discussed so that readers can find the latest research. In this study, "misconceptions" and "conceptual change" are two things that have a very close relationship in the process of identification and conceptual change and of course, each has a different character. The bibliometric analysis begins by searching the database Scopus and then is limited to thirty years 1992 to 2022. The database analyzed by the researcher was quoted as of August 8, 2023, and was presented in Figure 2.

The obtained database was saved in CSV, BibTex, and RIS formats before being analyzed using the software. Different file formats are used to adapt to the application software used. The bibliometric analysis was carried out by researchers with the help of tools and software such as Rstudio, VosViewer, Ms-Excel, and the Biblioshiny Program. According to Ai et al. (2023), Evergreen (2019), Guleria and Kaur (2021), Martins et al. (2022), and Sood et al. (2021), attractive visualization will give a good impression to the younger generation of readers and researchers. The workflow for this research is as follows:
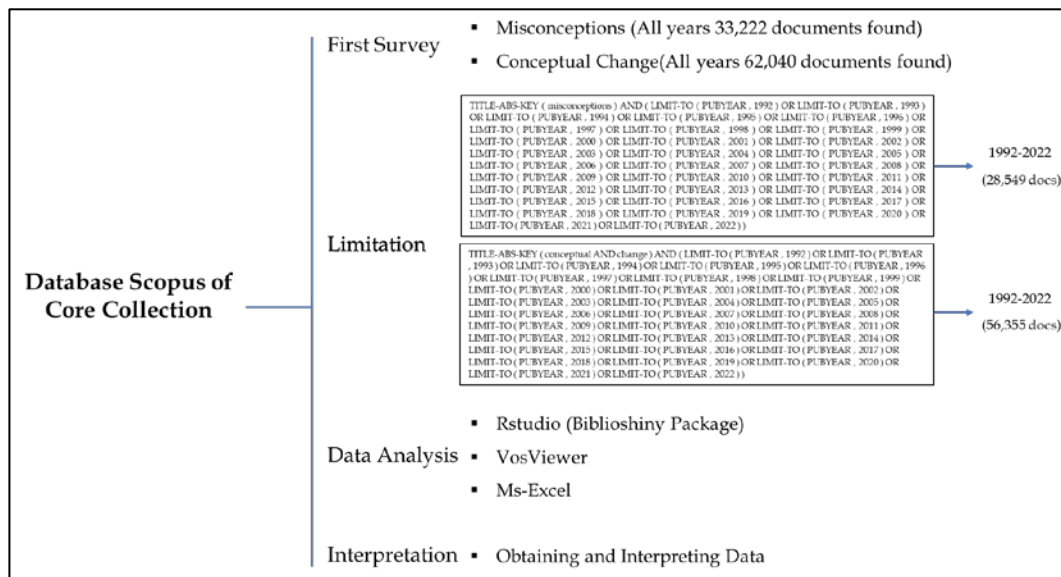
Figure 2. Flowchart Research

Findings / Results

Studies related to misconceptions and conceptual change during the last thirty years 1992-2022 will be presented according to the research questions created and supplemented with additional information. With existing knowledge, it will provide new insights into research topics that are closely related.

The Leading Information of Misconceptions and Conceptual Change

The information presented in Table 1 is the result of analysis and output from the Biblioshiny program using the Scopus database in the form of Bibtex. The main information presented can be information for further action as a source for conducting related research for researchers who focus on this topic. The following information is presented in Table 1.

Table1. Main Information

Description	Misconceptions	Conceptual change
Timespan	1992:2022	1992:2022
Source (Journals, Books, etc.)	8885	6450
Documents	28549	56355
Documents Average Age	10.9	11.9
Keywords Plus (ID)	45504	51831
Author's Keywords (DE)	34223	40995
Authors	54566	59253
Authors of single-authored docs	4625	3643
Single-authored docs	4966	3917
Co-Authors per doc	3.32	3.75
International co-authorships %	18.99	30.09

Table 1 profiles the last thirty years of misconceptions and conceptual change through main information such as timespan, source, documents, and authors. If looked carefully, the articles published are in journals and in the form of books, letters, and articles. Apart from that, the works produced during 1992-2022 were made by one writer and resulted from collaboration with the writer's colleagues. With proper cooperation and collaboration, more will be produced because it combines groups of knowledge into one.

Trend Publication Misconceptions and Conceptual Change

Annual Publications

Over the last thirty years, the track record in the field of misconceptions and conceptual change has experienced ups and downs. Below is presented the annual publication graphic data in Figure 3.

| (a) | (b) |
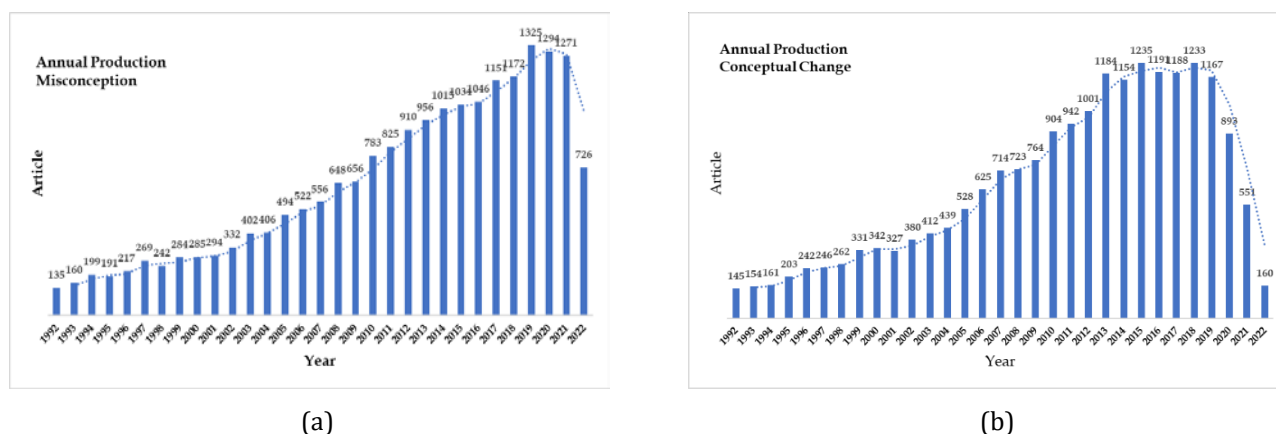
Figure 3. Annual Publication (a) Misconception, (b) Conceptual change

Figure 3 presents annual publications on misconceptions and conceptual change for the last thirty years. The trend in Figure 3 (a) of misconception topics from 1992 (135 docs) - 2019 (1325 docs) continues to increase, while in 2020 (1294 docs) - 2022 (726 docs) there is a decline in terms of the number of publications.

Then, in Figure 3 (b), conceptual change experiences a cumulative trend of ups and downs from 1992-2022. In 1992-2013, on average, there was a continuous increase. The most publications were in 2015 (1235 docs) and the least in 1992 (145 docs). However, in 2014-2019, it was consistent with a decline and increase that was not too far, whereas in 2020-2022 there was a pretty far decline. If traced further, that year, the Covid-19 pandemic occurred (Agbehadji et al., 2020; Reiss, 2020; Roux & Weyermann, 2020). This certainly impacts current research and publications due to the shift from face-to-face to virtual face-to-face. In line with this, existing policies also limit movement to carry out previous activities such as research on campus, school, or lab.

Annual Total Citation per Year

The number of publications recorded over the last thirty years certainly has citation records obtained from each article that has been published. The following data is presented in Table 2.

Table 2. Annual Publication 1992-2022

Misconceptions					Conceptual Change				
Year	N	MTCPA	MTCPY	CY	Year	N	MTCPA	MTCPY	CY
1992	135	37,76	1,18	32	1992	145	142,65	4,46	32
1993	160	25,84	0,83	31	1993	154	85,92	2,77	31
1994	199	44,29	1,48	30	1994	161	93,54	3,12	30
1995	191	45,74	1,58	29	1995	203	95,6	3,30	29
1996	217	40,83	1,46	28	1996	242	106,66	3,81	28
1997	269	35,84	1,33	27	1997	246	102,04	3,78	27
1998	242	45,98	1,77	26	1998	262	103,28	3,97	26
1999	284	56,55	2,26	25	1999	331	125,14	5,01	25
2000	285	41,95	1,75	24	2000	342	**164,37***	6,85	24
2001	294	53,89	2,34	23	2001	327	114,46	4,98	23
2002	332	63,67	2,89	22	2002	380	121,58	5,53	22
2003	402	49,12	2,34	21	2003	412	193,11	9,20	21

Table 2. Continued

Misconceptions					Conceptual Change				
Year	N	MTCPA	MTCPY	CY	Year	N	MTCPA	MTCPY	CY
2004	406	57,66	2,88	20	2004	439	141,13	7,06	20
2005	494	55,12	2,90	19	2005	528	116,67	6,14	19
2006	522	**70,18***	**3,90***	18	2006	625	106,5	5,92	18
2007	556	45,97	2,70	17	2007	714	109,69	6,45	17
2008	648	44,95	2,81	16	2008	723	106,7	6,67	16
2009	656	38,06	2,54	15	2009	764	95,96	6,40	15
2010	783	49,56	3,54	14	2010	904	97,17	6,94	14
2011	825	34,16	2,63	13	2011	942	94,8	7,29	13
2012	910	29,3	2,44	12	2012	1001	82,66	6,89	12
2013	956	35,66	3,24	11	2013	1184	75,54	6,87	11
2014	1015	29,36	2,94	10	2014	1154	67,42	6,74	10
2015	1034	28,27	3,14	9	2015	1235*	64,18	7,13	9
2016	1046	25,13	3,14	8	2016	1191	71,36	8,92	8
2017	1151	24,37	3,48	7	2017	1188	58,65	8,38	7
2018	1172	19,65	3,28	6	2018	1233	50,95	8,49	6
2019	1325*	17,17	3,43	5	2019	1167	43,3	8,66	5
2020	1294	13,89	3,47	4	2020	893	40,12	10,03	4
2021	1271	11,36	3,79	3	2021	551	36,11	12,04	3
2022	726	6,32	3,16	2	2022	160	31,74	**15,87***	2

N= Total, MTCPA = Mean Total Citation per Article, MTCPY = Mean Total Citation per Year, CY= Citable Years, *= The highest

Table 2 presents information regarding the highest number of citations over the last thirty years on misconceptions and conceptual change. The highest number of articles in the field of misconceptions was in 2019 (1325 docs). However, the number of citations in MTCPA in 2006 (70.18 cited) and MTCPY (3.90 cited**)**, while on the topic of conceptual change, the highest number of articles was in 2015 (1235 docs), and the number of citations in MTCPA in 2000 (164.37 cited) and MTCPY in 2022 (15.87 cited).

Authors and Affiliates Who Contributed Most to the Topic of Misconceptions and Conceptual Change

Top 15 Authors of Misconceptions and Conceptual Change

In the world of publications, one of the things of interest is the trend of research topics in the field of study. This information from research results can be used as a reference for published work. The top 15 authors are presented in Table 3.

Table 3. Top 15 Authors

Misconceptions			Conceptual change		
Author	Paper	Country	Author	Paper	Country
Samsudin, A.	54	Indonesia	Vosniadou, S.	46	Australia
Suhandi, A.	35	Indonesia	Sinatra, G.M	42	United States
Sinatra, G.M.	29	United States	Treagust, D.F.	27	Australia
Krause, S.	25	United States	Samsudin, A.	26	Indonesia
Appelbaum, P.	22	United States	Suhandi, A.	24	Indonesia
Siegrist, M.	21	Switzerland	Ruelland, D.	23	France
Kaniawati, I	20	Indonesia	Pickett, S.T.A.	21	United States
Bretz, S.L.	20	United States	Pahl-Wostl, C.	21	Germany
Herman, G.L.	19	United States	Mason, L.	21	Italy
Streveler, R.A.	18	United States	Willems, P.	19	Belgium
Ring, D.	18	United states	Geerlings, P	19	Belgium
Miller, R.L.	18	United States	Ford, J.D.	19	United Kingdom
Lidz, C.W.	17	United States	Verburg, P.H	17	Switzerland
Kendeou, P.	17	United States	Verschaffel, L.	17	Belgium
Rusdiana, D.	16	Indonesia	Lavorel, S.	16	New Zealand

Many articles someone publishes certainly have something to do with the field being studied. The topic of misconceptions is dominated by writers from Indonesia, namely Samsudin (54 papers) in the first place, the second place also from Indonesia, Suhandi (35 papers), and the third place from the United States, namely Sinatra (29 papers). Meanwhile, the

topic of conceptual change was dominated by Vosniadou from Australia (46 papers) from Australia, second place was Sinatra from the United States (42 papers), and Treagust from Australia (27 papers). The topics of misconceptions and conceptual change studied by each author have different domains; for example, Achmad Samsudin and Suhandi focus on science education and physics education. Meanwhile, Sinatra focused on educational psychology, and Vosniadou on cognitive psychology. Regarding this, each of them certainly has its character; only it is differentiated by different topics in depth. Apart from that, these two topics are generally still in the same group, namely assessment.

Top 10 Affiliates

The role of affiliates is always crucial because it is one of the requirements for submitting articles to the intended journal. The top affiliates are presented in Table 5.

Table 5. Top 10 Affiliate

Misconceptions		Conceptual change	
Affiliation	**Total paper**	**Affiliation**	**Total paper**
University of Toronto	224	Scientific Research National Center	512
Indonesian Education University	170	University of Toronto	459
Harvard Medical School	169	University College London	421
University of Washington	165	University of Melbourne	410
University of Oxford	158	Chinese Academy of Science	398
The University of Sydney	153	University of Washington	386
University College London	143	The University of British Columbia	385
University of California	143	Wageningen University	376
The Ohio State University	142	University of Cambridge	362
University of Melbourne	141	University Oxford	355

Table 5 presents the top 10 affiliates over the last thirty years on misconceptions and conceptual change research topics. The affiliates that have contributed and influenced the most on the topic of misconceptions are the University of Toronto (224 papers), the Indonesian Education University (170 papers), and Harvard Medical School (169 papers). In comparison, the topic of conceptual change is the Center National de la Recherche Scientifique (512 papers), University of Toronto (459 papers), and University College London (421 papers). The affiliates above certainly have a deep field of scientific studies on misconceptions and conceptual change, which are then made into articles published and indexed by Scopus.

The Most Contribute Country of Topic Misconceptions and Conceptual Change

Top 15 Country Production Over Time

The country's productivity cannot be separated from the productivity of authors and affiliates. In this way, researchers make a real contribution to the country by creating policies and making decisions (Kaya et al., 2019; Kern et al., 2019; Schildkamp, 2019). Below are presented the top 15 countries with the most attributions in Figure 4.
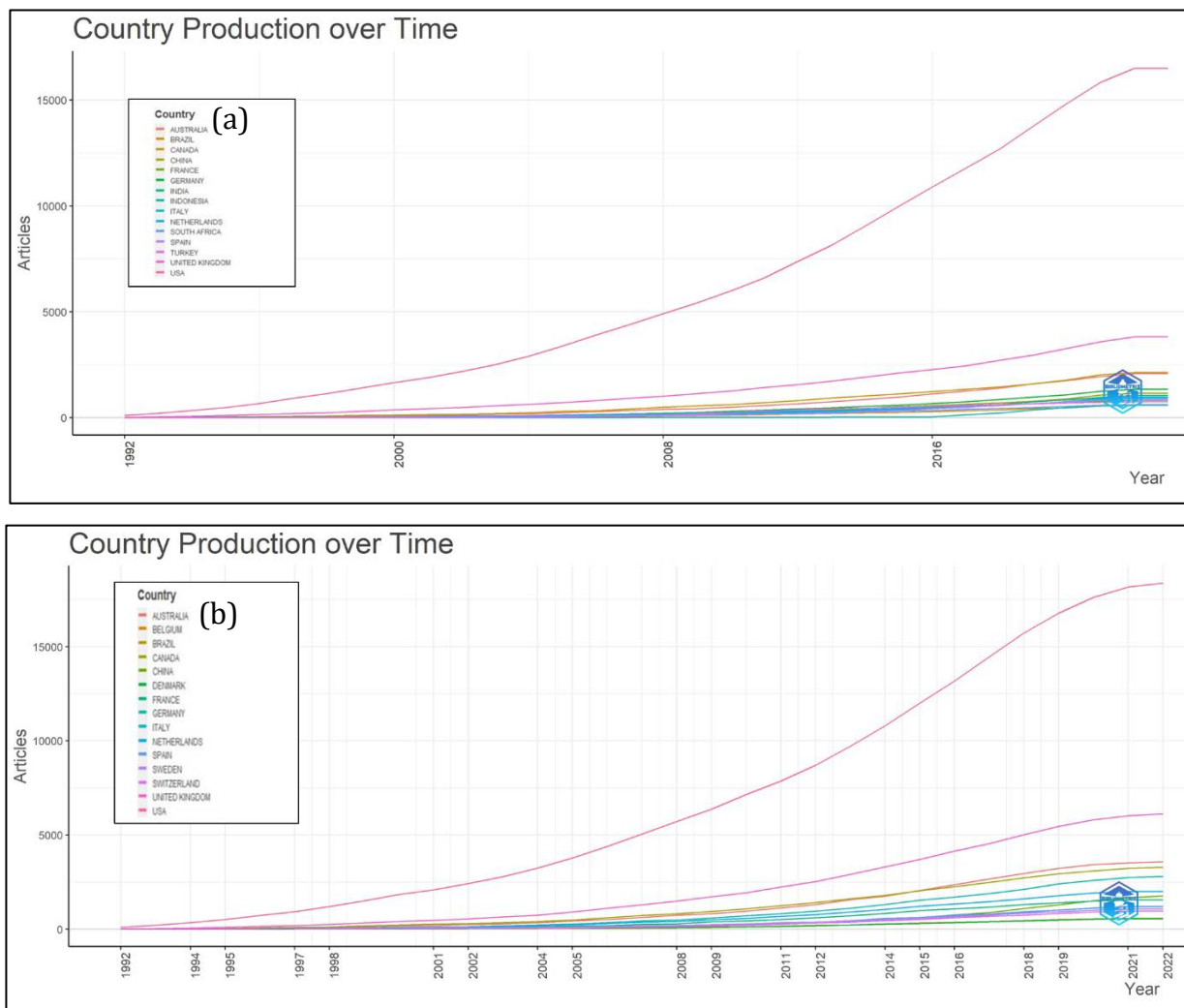
Figure 4. Top 15 Countries (a) Misconception, (b) Conceptual change

Figure 4 presents the most productive countries on misconceptions and conceptual change throughout the year. Regarding misconceptions, the most productive countries are Australia, Brazil, and Canada, while on conceptual change, the most productive countries are Australia, Belgium, and Brazil. A country's productivity can only be seen from the number of articles published, but not based on the quality of each article published.

The Most Corresponding Author Countries

In the article submission process, a corresponding person is responsible for the article regarding content and credibility. Usually, the corresponding comes from the country that produced the article. The following shows the most correspondence in Figure 5.
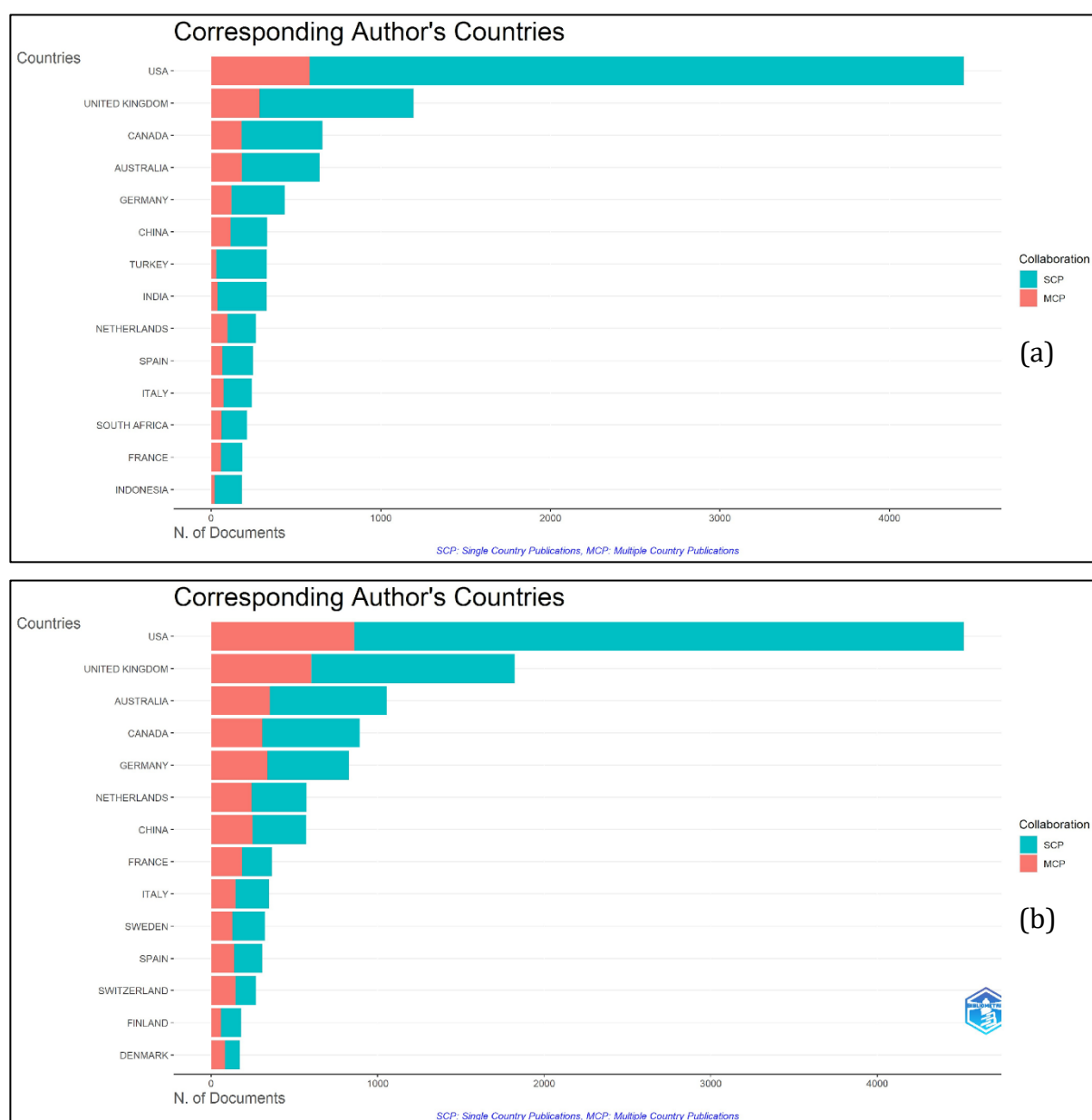
Figure 5. Most Cited Countries (a) Misconception, (a) Conceptual Change

Figure 5 presents information regarding the corresponding author in collaboration, divided into SCP=Single-country publication dan MCP= Multiple-country publication. The topic misconception first stage occupied by USA (4437 docs) with distribution (SCP=3856 and MCP=581), ranked second in the UK (1193 docs) with distribution (SCP=906 and MCP=281), and ranked third in the country Canada (655 docs) with distribution (SCP=476 and MCP=179). Then for the first level conceptual change topic occupied by the USA country (8316 docs) with distribution (SCP=5276 and MCP=3040), and ranked second in the UK (7498 docs) with distribution (SCP=5236 and MCP=179), and ranked third in the country Australia (3512 docs) with distribution (SCP=2012 and MCP=1500). According to Erdoğan (2019), Haug and Mork (2021), and Sumardi et al. (2020), collaboration is one of the skills and abilities required in the 21st century 21 because it has a significant role in the progress of a country's science globally. In that way, misconceptions and conceptual changes continue to increase until the understanding of something corresponds to what has been delivered by the experts.

The Most Relevant Keyword of Misconceptions and Conceptual Change

The Most Relevant Word

Relevant words are most widely used or related to the discussed or studied research topic. The following most relevant words that are most often used in the topic of misconceptions and conceptual change 1992-2022 are presented in Figure 6.
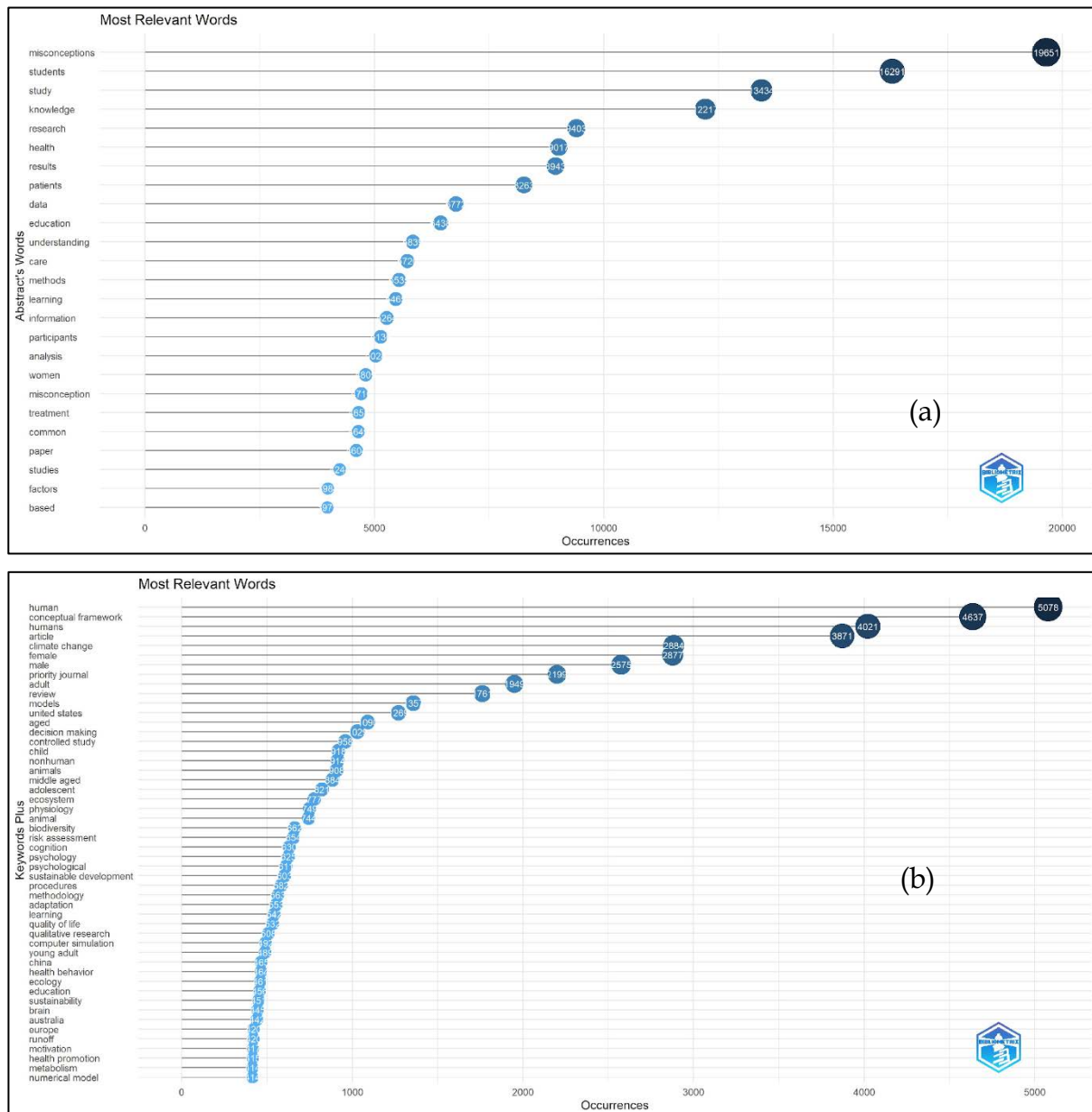
Figure 6. Most Relevant Word (a) Misconception, (b) Conceptual Change

Figure 6 provides information regarding the words most related to misconceptions and conceptual change. The most relevant words in misconception are "misconceptions" with a total of 19651 words, continue with "students" with a total of 16291 words, and the third is "study" with 13434 words. Meanwhile, on conceptual change, the most relevant word is "human" with word 5078. The second most relevant word is "conceptual framework" with the word 4637, and the third is "human" with the word 4021. In other words, it also becomes an essential part of the research topic. According to C.-H. Chen (2020), D. Li, Opaza et al. (2020), and Tang et al. (2020), frequently used words are a sign that the topic being studied is closely related to each other.

Network Visualization

Apart from relevant words, some occurrence words can present relationships between words through network visualization. Network visualization plays a role in finding updates between comments and can be used as a way to determine research gaps. The following visualization of word occurrences is presented in Figure 7.

(a)

(b)
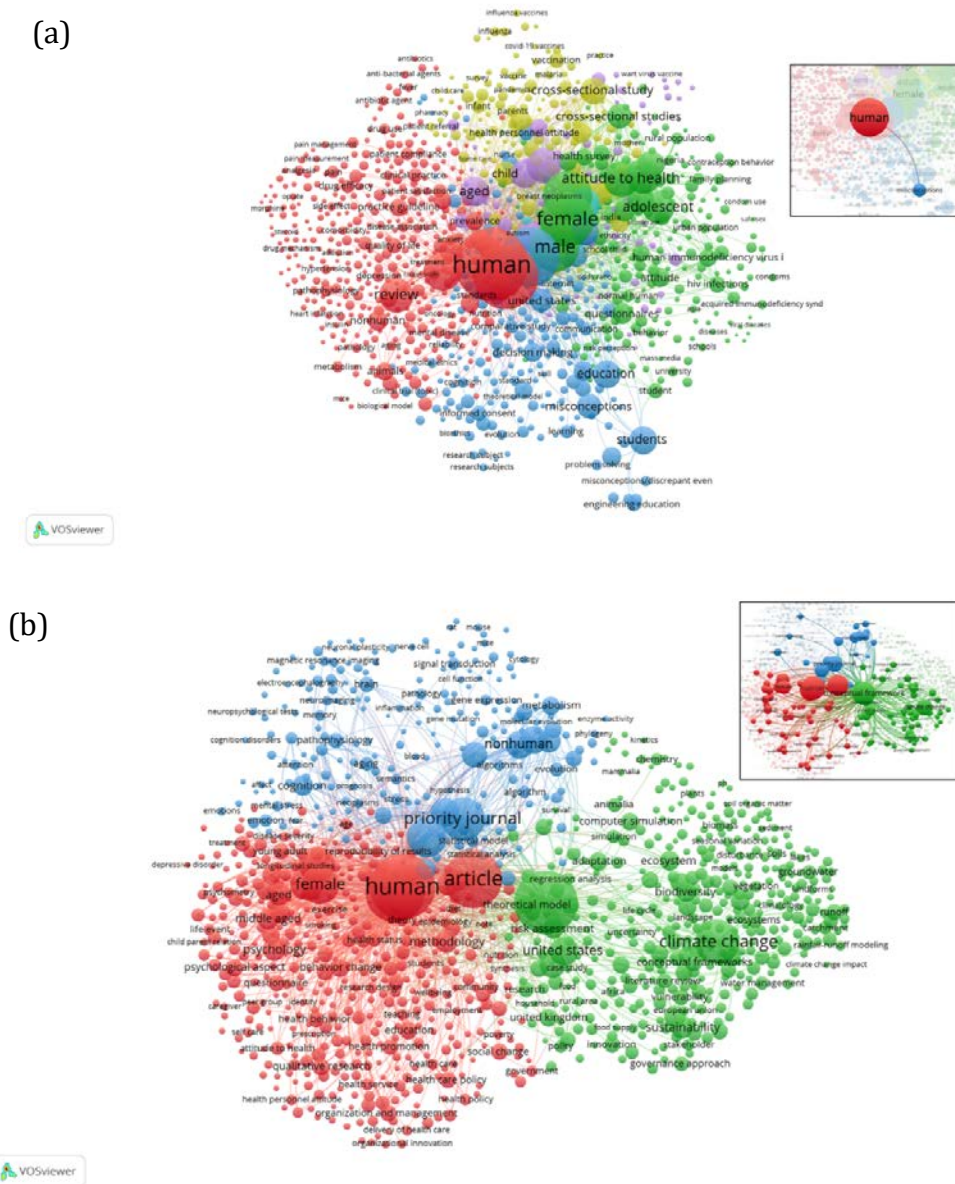
Figure 7. Network Visualization (a) Misconception, (b) Conceptual Change

Figure 7 presents the relationship between words with specific color clusters. Figure 7 (a) is a word relationship in the misconceptions field containing 1000 items (6 clusters). Cluster 1 (392 items), Cluster 2 (202 items), Cluster 3 (192 items), Cluster 4 (144 items), Cluster 5 (68 items), and Cluster 6 (2 items). The most related words between clusters are human, misconception, review, female, education, and students. In this field of study, misconceptions have the closest relationship to humans. According to Chua et al. (2020), Fleming et al. (2021), Miftakhuddin et al. (2019), and Wen et al. (2022), misconceptions do occur in humans so the relationship between them is very close. However, there is another word relationship that can be the potential for study in the future regarding misconceptions.

Figure 7 (b) is the relationship of words to the topic conceptual change. Based on the food network visualization results, 1000 items were obtained and divided into 3 clusters. Cluster 1 (410 items), Cluster 2 (374 items), and Cluster 3 (216 items). The most appear frequently or have the most significant correlations between words are human, climate change, conceptual framework, article, priority journal, and education. Visualization of the given information that conceptual change also has a connection as close to humans as it is to misconceptions. The big and small words that appear have meant that they have the most relationship and have the potential to be used as a topic for future research on the topic of misconceptions and conceptual change (Flynn & Hardman, 2019; Mason & Zaccoletti, 2021; Phommanee et al., 2023).

The Relationship Between Misconceptions and Conceptual Change in Science Education
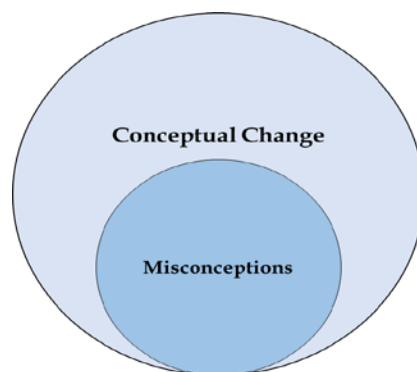
Figure 8. Relationship Between Misconceptions and Conceptual Change

Figure 8 shows the relationship between misconceptions and conceptual change is presented. Misconceptions in learning often become obstacles in the process of achieving deep understanding. However, conceptual change is key to overcoming these misconceptions. Incorrect or incomplete concepts need to be addressed with strategies that encourage student thinking changes.

Conclusion

The primary information provides a general overview of how these two topics are developing in the world through the Scopus database record tract such as; sources, documents, and authors' collaboration. This information offers a breakthrough for researchers to participate in this topic. Through this information, collaboration opportunities in the field of misconceptions and conceptual change can be identified from international authorships such as single authors and Co-authors. In line with Bhatt (2001), Pea (2004), Rejeb et al. (2021), and Savoia et al. (2016) stated that collaboration is one aspect that needs to be considered in the current era of technological and information development because it can bring together bright ideas and execute them to make them a reality.

The publication trend on the topic being studied has increased from year to year. However, there was a decline in 2019, one of the causes of which was the Covid-19 pandemic, which limited social activities. In this case, research and learning are also limited. According to Ball et al. (2021) and Selvaraj et al. (2021), the restrictions that apply during the pandemic impact all aspects, including education and research. One piece of evidence that can strengthen these results is the decrease in the number of publications and citations on the topic of misconceptions and conceptual change. According to Azizi et al. (2021), Birkle et al. (2020), Makri et al. (2021), and Sghir et al. (2023), the fluctuating number of publications is normal in the world of research because there are many new studies and new information for further innovation. In additions C. Chen and Song (2019), and Singh and Thurman (2019), the number of citations means that the work is most often used as a reference in the research in question. Countries that produce a large number of articles certainly cannot be separated from collaboration between researchers, institutions, and even countries (Churiyah et al., 2020; Ferri et al., 2020).

The author who contributed most to the topic of misconceptions came from Indonesia, while the topic of conceptual change came from Australia. The researchers are both involved in this field which has a very close relationship. Based on these results, it can be seen that the number of publications does not guarantee the quality of the article. In line with what was stated by Baas et al. (2020), Khatter et al. (2021), and Paul et al. (2021), quantity does not guarantee the quality of an article, be it a journal, proceedings, or book. Therefore, there are indexers with specific levels, for example, in Scopus Q1-Q4, which have their criteria and strict selection so that the articles published are high quality (Oldac, 2022; Petr et al., 2021).

According to Washburn and Skitka (2018), consistency in science will have a significant impact on the science being studied. In this way, it is rare to find someone who has made a significant contribution to two different scientific studies because each of them has their field of scientific research. In line with what O'Dwyer et al. (2016) said, that the deeper a person's study, the more expert that person will be. On the other hand, an institution as a place for research only provides information that the institution has in-depth studies on the topic being discussed. Indirectly, it is also part of the contribution to the country.

According to Frustaci et al. (2017) and K. Zhou et al. (2015), through technological developments everyone can access so much information from one end of the world. That way, it is not something new if there are researchers who are competent in a field. According to Mian et al. (2020), Sadeghi (2019), and Toader et al. (2021), each institution and study program has its strengths and weaknesses, which can continue to be developed for studies in the field of science. The words that appear in research on misconceptions and conceptual change indicate how they relate to the topic being discussed, for example, the relationship between humans and misconceptions and conceptual change. According to

Loyens et al. (2015), and Metcalf and Crawford (2016), misconceptions and conceptual change studies use human subjects as samples of research and learning. In addition, we can find the latest research on the topics discussed through network visualization. This can be obtained by connecting visualization results to an issue that has a density that could be more striking.

Apart from that, it is very important to know the interest between the variables being studied to find the latest research in the future. In this case, misconceptions and conceptual change are very closely related so that they can be combined into one for future research (Asterhan & Resnick, 2020; Grospietsch & Mayer, 2018; Thacker et al., 2020). Apart from that, the study of misconceptions and conceptual change still has excellent potential to continue to be developed in sharing sub-materials in science learning. It's necessary to understand the characteristics of the sample, school, and institution being targeted.

Misconceptions are errors in a person's understanding in connecting an existing concept with a newly accepted idea, thereby forming a wrong concept that contradicts the expert's conception. According to van Driel et al. (1998), Vaughn et al. (2020), and Zidny et al. (2020), differences in conceptions must be handled, and concepts can be proven empirically and rationally. In science learning, misconceptions are often found because there are many concepts, such as physics, chemistry, biology, and astronomy. Misconceptions don't only happen to students; they can also happen to teachers. According to Bao and Fritchman (2021), La Braca and Kalman (2021), and Pinto et al. (2023), conceptual errors can occur due to several things, such as preconceptions that students already have, a person's limited reasoning, inadequate understanding abilities, and learning concepts that are not emphasized enough. Correct reference sources and teachers who make mistakes in delivering. This way, various efforts are made to remediate wrong misconceptions, especially among students, using conceptual change.

According to Anggoro et al. (2019), Fuadi et al. (2020), Potvin et al. (2020), and Stern et al. (2020), conceptual change is a process carried out to replace wrong conceptions with correct conceptions in line with experts. Usually, the process of conceptual change is carried out using assistance such as book development, student worksheets, videos, games, and many more. Several studies assume that conceptual change is a learning model to remediate misconceptions. In this way, it can be concluded that misconceptions have a close relationship with conceptual change.

Research related to misconceptions is usually carried out only to identify students' conceptions and is used as evaluation material before starting learning (Miedema et al., 2022; Park, 2019; Tumanggor et al., 2020; K.-H. Yang & Lu, 2021). In determining whether students fall into the misconception group, trials are carried out in the form of tier questions, be it two-tier, three-tier, four-tier, or even up to five-tier (Anam et al., 2019; Laliyo et al., 2019; Önder Çelikkanlı & Kızılcık, 2022; D.-C. Yang & Sianturi, 2021). Through this test, we can map the profile of students with wrong conceptions regarding the material being tested. After that, conceptual change will play a role in remediating false concepts through learning with the help of learning models, learning approaches, media, and learning strategies.

This article discusses and presents trends in research topics on misconceptions and conceptual change over the last thirty years 1992-2022. Based on the description and discussion that has been carried out, it can be concluded that this topic is one of the topics that needs to be discussed and followed up because it is specifically related to learning for life for every individual, especially for students. Researchers from Australia, Indonesia, and the United States dominate the research topic of misconceptions and conceptual change. Meanwhile, the campuses that contributed most to the topic of misconceptions were the University of Toronto, Indonesian Education University, and Harvard Medical School. Apart from that, the topic of conceptual change is dominated by affiliates of the Scientific Research National Center, University of Toronto, and University College London. Additionally, as a piece of new knowledge, research on misconceptions and conceptual change also covers details such as the nature of misconceptions, the learning environment, cognitive strategies, the benefits of representation, and cognitive conflict. Based on the survey that has been carried out, this study can provide information and insight for readers regarding the topics of misconceptions and conceptual change.

Based on this study, several opportunities and the need for studying misconceptions and concepts in science education are as follows:

1. A way forward to capitalize on the growing body of research on misconceptions in education is to integrate the findings into the education curriculum at all levels, and provide adequate training and support for teachers to identify and address misconceptions that students may have.

2. The results of this research do not yet provide details regarding the use of AR and VR which is associated with improving misconceptions and conceptual changes. So, future research can integrate technology in changing misconceptions and conceptual changes.

Limitations in this study include: (a) The research data used is only based on the Scopus database, (b) The document string used: TITLE-ABS-KEY (Misconception AND Conceptual Change) for 1992-2022, and (c) This research focuses as a preliminary study to see research opportunities in science education.

Authorship Contribution Statement

Amiruddin: Research design and concept, data acquisition, drafting research manuscript, revision, supervision. Samsudin: Drafting manuscript, research data analysis, technical and material support, research data acquisition. Suhandi: Technical and material support, data acquisition. Coştu: Translating, proofreading, final approval.

References

Agbehadji, I. E., Awuzie, B. O., Ngowi, A. B., & Millham, R. C. (2020). Review of big data analytics, artificial intelligence, and nature-inspired computing models towards accurately detecting COVID-19 pandemic cases and contact tracing. *International Journal of Environmental Research and Public Health, 17*(15), Article 5330. https://doi.org/10.3390/ijerph17155330

Ahonen, L., Loeber, R., & Brent, D. A. (2019). The association between serious mental health problems and violence: Some common assumptions and misconceptions. *Trauma, Violence, and Abuse, 20*(5), 613-625. https://doi.org/10.1177/1524838017726423

Ai, S., Li, Y., Tao, J., Zheng, H., Tian, L., Wang, Y., Wang, Z., & Liu, W. J. (2023). Bibliometric visualization analysis of gut-kidney axis from 2003 to 2022. *Frontiers in Physiology, 14,* Article 1176894. https://doi.org/10.3389/fphys.2023.1176894

Akcan, E. (2022). An analytical overview of the studies on the life studies lesson: Bibliometric analysis based on the Web of science database. *Journal of Educational Studies and Multidisciplinary Approaches, 2*(2), 213-227. https://doi.org/10.51383/jesma.2022.53

Akour, M., & Alenezi, M. (2022). Higher education future in the era of digital transformation. *Education Sciences, 12*(11), Article 784. https://doi.org/10.3390/educsci12110784

Allen, K.-A., Gray, D. L., Baumeister, R. F., & Leary, M. R. (2022). The need to belong: A deep dive into the origins, implications, and future of a foundational construct. *Educational Psychology Review, 34*, 1133-1156. https://doi.org/10.1007/s10648-021-09633-6

Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses—Theoretical background and empirical results. *British Journal of Educational Technology, 51*(3), 611-628. https://doi.org/10.1111/bjet.12900

Anam, R. S., Widodo, A., Sopandi, W., & Wu, H.-K. (2019). Developing a five-tier diagnostic test to identify students' misconceptions in science: An example of the heat transfer concepts. *İlköğretim Online, 18*(3), 1014-1029. https://doi.org/10.17051/ilkonline.2019.609690

Anggoro, S., Widodo, A., Suhandi, A., & Treagust, D. F. (2019). Using a discrepant event to facilitate preservice elementary teachers' conceptual change about force and motion. *Eurasia Journal of Mathematics, Science and Technology Education, 15*(8), Article em1737. https://doi.org/10.29333/ejmste/105275

Asterhan, C. S. C., & Resnick, M. S. (2020). Refutation texts and argumentation for conceptual change: A winning or a redundant combination? *Learning and Instruction, 65*, Article 101265. https://doi.org/10.1016/j.learninstruc.2019.101265

Azizi, M. R., Atlasi, R., Ziapour, A., Abbas, J., & Naemi, R. (2021). Innovative human resource management strategies during the COVID-19 pandemic: A systematic narrative review approach. *Heliyon, 7*(6), Article e07233 https://doi.org/10.1016/j.heliyon.2021.e07233

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus is a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies, 1*(1), 377-386. https://doi.org/10.1162/qss_a_00019

Ball, C., Huang, K.-T., & Francis, J. (2021). Virtual reality adoption during the COVID-19 pandemic: A uses and gratifications perspective. *Telematics and Informatics, 65,* Article 101728. https://doi.org/10.1016/j.tele.2021.101728

Bao, L., & Fritchman, J. C. (2021). Knowledge integration in student learning of Newton's third law: Addressing the action-reaction language and the implied causality. *Physical Review Physics Education Research, 17*, Article 020116. https://doi.org/10.1103/PhysRevPhysEducRes.17.020116

Bhatt, G. D. (2001). Knowledge management in organizations: Examining the interaction between technologies,

techniques, and people. *Journal of Knowledge Management, 5*(1), 68-75. https://doi.org/10.1108/13673270110384419

Birkle, C., Pendlebury, D. A., Schnell, J., & Adams, J. (2020). Web of Science as a data source for research on scientific and scholarly activity. *Quantitative Science Studies, 1*(1), 363-376. https://doi.org/10.1162/qss_a_00018

Broström, S. (2017). A dynamic learning concept in early years' education: A possible way to prevent schoolification. *International Journal of Early Years Education, 25*(1), 3-15. https://doi.org/10.1080/09669760.2016.1270196

Chen, C., & Song, M. (2019). Visualizing a field of research: A methodology of systematic scientometric reviews. *PLOS ONE, 14*(10), Article e0223994. https://doi.org/10.1371/journal.pone.0223994

Chen, C.-H. (2020). Impacts of augmented reality and a digital game on students' science learning with reflection prompts in multimedia learning. *Educational Technology Research and Development, 68*, 3057-3076. https://doi.org/10.1007/s11423-020-09834-w

Chua, L., Harrison, M. E., Fair, H., Milne, S., Palmer, A., Rubis, J., Thung, P., Wich, S., Büscher, B., Cheyne, S. M., Puri, R. K., Schreer, V., Stępień, A., & Meijaard, E. (2020). Conservation and the social sciences: Beyond critique and co-optation. A case study from orangutan conservation. *People and Nature, 2*(1), 42-60. https://doi.org/10.1002/pan3.10072

Churiyah, M., Sholikhan, S., Filianti, F., & Sakdiyyah, D. A. (2020). Indonesia education readiness conducting distance learning in Covid-19 pandemic situation. *International Journal of Multicultural and Multireligious Understanding, 7*(6), 491-507. https://doi.org/10.18415/ijmmu.v7i6.1833

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133,* 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

Erdoğan, V. (2019). Integrating 4C skills of 21st century into 4 language skills in EFL classes. *International Journal of Education and Research, 7*(11), 113-124. https://bit.ly/3JVCIYC

Evergreen, S. (2019). *Effective data visualization: The right chart for the right data* (2nd ed.). SAGE publications.

Fadillah, A., & Salirawati, D. (2018). Analysis of misconceptions of chemical bonding among tenth grade senior high school students using a two-tier test. *AIP Conference Proceedings, 2021*(1), Article 080002. https://doi.org/10.1063/1.5062821

Fauth, B., Decristan, J., Decker, A.-T., Büttner, G., Hardy, I., Klieme, E., & Kunter, M. (2019). The effects of teacher competence on student outcomes in elementary science education: The mediating role of teaching quality. *Teaching and Teacher Education, 86*, Article 102882. https://doi.org/10.1016/j.tate.2019.102882

Ferri, F., Grifoni, P., & Guzzo, T. (2020). Online learning and emergency remote teaching: Opportunities and challenges in emergency situations. *Societies, 10*(4), Article 86. https://doi.org/10.3390/soc10040086

Fleming, W., Hayes, A. L., Crosman, K. M., & Bostrom, A. (2021). Indiscriminate, irrelevant, and sometimes wrong: Causal misconceptions about climate change. *Risk Analysis, 41*(1), 157-178. https://doi.org/10.1111/risa.13587

Flynn, S., & Hardman, M. (2019). The use of interactive fiction to promote conceptual change in science: A forceful adventure. *Science and Education, 28*, 127-152. https://doi.org/10.1007/s11191-019-00032-6

Frustaci, M., Pace, P., Aloi, G., & Fortino, G. (2017). Evaluating critical security issues of the IoT world: Present and future challenges. *IEEE Internet of Things Journal, 5*(4), 2483-2495. https://doi.org/10.1109/JIOT.2017.2767291

Fuadi, F. N., Sopandi, W., Priscylio, G., Hamdu, G., & Mustikasari, L. (2020). Students' conceptual changes on the air pressure learning using predict-observe-explain strategy. *Mimbar Sekolah Dasar, 7*(1), 70-85. https://doi.org/10.17509/mimbar-sd.v7i1.22457

Fuadiah, N. F., Suryadi, D., & Turmudi. (2019). Teaching and Learning Activities in classroom and their impact on student misunderstanding: A case study on negative integers. *International Journal of Instruction, 12*(1), 407-424. https://doi.org/10.29333/iji.2019.12127a

Gnidovec, T., Žemlja, M., Dolenec, A., & Torkar, G. (2020). Using augmented reality and the structure–behavior–function model to teach lower secondary school students about the human circulatory system. *Journal of Science Education and Technology, 29,* 774-784. https://doi.org/10.1007/s10956-020-09850-8

Gómez-Carrasco, C. J., Miralles-Martinez, P., Fontal, O., & Ibañez-Etxeberria, A. (2020). Cultural heritage and methodological approaches—an analysis through initial training of history teachers (Spain–England). *Sustainability, 12*(3), Article 933. https://doi.org/10.3390/su12030933

Grospietsch, F., & Mayer, J. (2018). Professionalizing pre-service biology teachers' misconceptions about learning and the brain through conceptual change. *Education Sciences, 8*(3), Article 120. https://doi.org/10.3390/educsci8030120

Guleria, D., & Kaur, G. (2021). Bibliometric analysis of ecopreneurship using VOSviewer and RStudio Bibliometrix, 1989-

2019. *Library Hi Tech, 39*(4), 1001-1024. https://doi.org/10.1108/LHT-09-2020-0218

Haug, B. S., & Mork, S. M. (2021). Taking 21st century skills from vision to classroom: What teachers highlight as supportive professional development in the light of new demands from educational reforms. *Teaching and Teacher Education, 100,* Article 103286. https://doi.org/10.1016/j.tate.2021.103286

Kahu, E. R., & Nelson, K. (2018). Student engagement in the educational interface: Understanding the mechanisms of student success. *Higher Education Research and Development, 37*(1), 58-71. https://doi.org/10.1080/07294360.2017.1344197

Kaniawati, I., Fratiwi, N. J., Danawan, A., Suyana, I., Samsudin, A., & Suhendi, E. (2019). Analyzing students' misconceptions about Newton's laws through four-tier Newtonian test (FTNT). *Journal of Turkish Science Education, 16*(1), 110-122. https://bit.ly/3UP3atc

Kaya, I., Colak, M., & Terzi, F. (2019). A comprehensive review of fuzzy multi criteria decision making methodologies for energy policy making. *Energy Strategy Reviews, 24*, 207-228. https://doi.org/10.1016/j.esr.2019.03.003

Kern, F., Rogge, K. S., & Howlett, M. (2019). Policy mixes for sustainability transitions: New approaches and insights through bridging innovation and policy studies. *Research Policy, 48*(10), Article 103832. https://doi.org/10.1016/j.respol.2019.103832

Khatter, A., Naughton, M., Dambha-Miller, H., & Redmond, P. (2021). Is rapid scientific publication also high quality? Bibliometric analysis of highly disseminated COVID-19 research papers. *Learned Publishing, 34*(4), 568-577. https://doi.org/10.1002/leap.1403

Kınık Topalsan, A., & Bayram, H. (2019). Identifying prospective primary school teachers' ontologically categorized misconceptions on the topic of "Force and Motion". *Journal of Turkish Science Education, 16*(1), 85-109. https://bit.ly/3QDsnnI

Kiray, S. A., & Simsek, S. (2021). Determination and evaluation of the science teacher candidates' misconceptions about density by using four-tier diagnostic test. *International Journal of Science and Mathematics Education, 19*, 935-955. https://doi.org/10.1007/s10763-020-10087-5

La Braca, F., & Kalman, C. S. (2021). Comparison of labatorials and traditional labs: The impacts of instructional scaffolding on the student experience and conceptual understanding. *Physical Review Physics Education Research, 17*(1), Article 010131. https://doi.org/10.1103/PhysRevPhysEducRes.17.010131

Laliyo, L. A. R., Botutihe, D. N., & Panigoro, C. (2019). The development of two-tier instrument based on distractor to assess the conceptual understanding level and student misconceptions in explaining redox reactions. International Journal of Learning, *Teaching and Educational Research, 18*(9), 216-237. https://doi.org/10.26803/ijlter.18.9.12

Leacock, T. L., & Nesbit, J. C. (2007). A framework for evaluating the quality of multimedia learning resources. *Journal of Educational Technology and Society, 10*(2), 44-59. https://www.jstor.org/stable/jeductechsoci.10.2.44

Li, D., Opazo, C. R., Yu, X., & Li, H. (2020). Word-level deep sign language recognition from video: A new large-scale dataset and methods comparison. In *Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision.* (pp. 1459-1469). IEEE. https://doi.org/10.1109/WACV45572.2020.9093512

Loyens, S. M. M., Jones, S. H., Mikkers, J., & van Gog, T. (2015). Problem-based learning as a facilitator of conceptual change. *Learning and Instruction, 38,* 34-42. https://doi.org/10.1016/j.learninstruc.2015.03.002

Makri, A., Vlachopoulos, D., & Martina, R. A. (2021). Digital escape rooms as innovative pedagogical tools in education: A systematic literature review. *Sustainability, 13*(8), Article 4587. https://doi.org/10.3390/su13084587

Martins, J., Gonçalves, R., & Branco, F. (2022). A bibliometric analysis and visualization of e-learning adoption using VOSviewer. *Universal Access in the Information Society*. Advance online publication. https://doi.org/10.1007/s10209-022-00953-0

Mason, L., & Zaccoletti, S. (2021). Inhibition and conceptual learning in science: A review of studies. *Educational Psychology Review, 33,* 181-212. https://doi.org/10.1007/s10648-020-09529-x

Metcalf, J., & Crawford, K. (2016). Where are human subjects in big data research? The emerging ethics divide. *Big Data and Society, 3*(1), 1-14 https://doi.org/10.1177/2053951716650211

Mian, S. H., Salah, B., Ameen, W., Moiduddin, K., & Alkhalefah, H. (2020). Adapting universities for sustainability education in industry 4.0: Channel of challenges and opportunities. *Sustainability, 12*(15), Article 6100. https://doi.org/10.3390/su12156100

Miedema, D., Aivaloglou, E., & Fletcher, G. (2022). Identifying SQL misconceptions of novices: Findings from a think-aloud study. *ACM Inroads, 13*(1), 52-65. https://doi.org/10.1145/3514214

Miftakhuddin, Mustadi, A., & Zulfiati, H. M. (2019). Misconceptions between social studies and social sciences among pre-service elementary teachers. *International Journal of Education, 12*(1), 16-25. https://doi.org/10.17509/ije.v12i1.17514

Moodley, K., & Gaigher, E. (2019). Teaching electric circuits: Teachers' perceptions and learners' misconceptions. *Research in Science Education, 49,* 73-89. https://doi.org/10.1007/s11165-017-9615-5

Mufit, F., Festiyed, Fauzan, A., & Lufri. (2019). The application of real experiments and video analysis in the CCBL model to remediate the misconceptions about motion concept. *Journal of Physics: Conference Series, 1317*, Article 012156. https://doi.org/10.1088/1742-6596/1317/1/012156

O'Dwyer, M., Peklar, J., McCallion, P., McCarron, M., & Henman, M. C. (2016). Factors associated with polypharmacy and excessive polypharmacy in older people with intellectual disability differ from the general population: A cross-sectional observational nationwide study. *BMJ Open, 6*(4), Article e010505. https://doi.org/10.1136/bmjopen-2015-010505

Oldac, Y. I. (2022). Global science and the muslim world: Overview of muslim-majority country contributions to global science. *Scientometrics*, *127,* 6231-6255. https://doi.org/10.1007/s11192-022-04517-0

Önder Çelikkanlı, N., & Kızılcık, H. Ş. (2022). A review of studies about four-tier diagnostic tests in physics education. *Journal of Turkish Science Education, 19*(4), 1291-1311. http://doi.org/10.36681/tused.2022.175

Park, M. (2019). Effects of simulation-based formative assessments on students' conceptions in physics. *EURASIA Journal of Mathematics, Science and Technology Education, 15*(7), Article em1722. https://doi.org/10.29333/ejmste/103586

Paul, J., Lim, W. M., O'Cass, A., Hao, A. W., & Bresciani, S. (2021). Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR). *International Journal of Consumer Studies, 45*(4), O1–O16. https://doi.org/10.1111/ijcs.12695

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. In E. A. Davis & N. Miyake (Eds.), *Scaffolding* (1st ed., pp. 423-451)*.* Psychology Press. https://doi.org/10.4324/9780203764411-6

Peel, A., Sadler, T. D., & Friedrichsen, P. (2019). Learning natural selection through computational thinking: Unplugged design of algorithmic explanations. *Journal of Research in Science Teaching, 56*(7), 983-1007. https://doi.org/10.1002/tea.21545

Pekrun, R. (2022). Emotions in reading and learning from texts: Progress and open problems. *Discourse Processes, 59*(1-2), 116-125. https://doi.org/10.1080/0163853X.2021.1938878

Petr, M., Engels, T. C. E., Kulczycki, E., Dušková, M., Guns, R., Sieberová, M., & Sivertsen, G. (2021). Journal article publishing in the social sciences and humanities: A comparison of Web of Science coverage for five European countries. *PLOS ONE*, *16*(4), Article e0249879. https://doi.org/10.1371/journal.pone.0249879

Phommanee, W., Plangsorn, B., & Siripipattanakul, S. (2023). A systematic review of changing conceptual to practice in learning experience design: Text mining and bibliometric analysis. *Contemporary Educational Technology, 15*(4), Article ep453. https://doi.org/10.30935/cedtech/13480

Pinto, G., Castro-Acuña, C. M., López-Hernández, I., & Alcázar Montero, V. (2023). Learning difficulties in the interpretation of matter at the molecular level by university students—a case study: Dissolution of oxygen in water. *Education Sciences, 13*(8), Article 781. https://doi.org/10.3390/educsci13080781

Potvin, P., Nenciovici, L., Malenfant-Robichaud, G., Thibault, F., Sy, O., Mahhou, M. A., Bernard, A., Allaire-Duquette, G., Blanchette Sarrasin, J., Brault Foisy, L.-M., Brouillette, N., St-Aubin, A.-A., Charland, P., Masson, S., Riopel, M., Tsai, C.-C., Belanger, M., & Chastenay, P. (2020). Models of conceptual change in science learning: Establishing an exhaustive inventory based on support given by articles published in major journals. *Studies in Science Education, 56*(2), 157-211. https://doi.org/10.1080/03057267.2020.1744796

Prahani, B. K., Amiruddin, M. Z. B., Suprapto, N., Deta, U. A., & Cheng, T.-H. (2022). The trend of physics education research during COVID-19 pandemic. *International Journal of Educational Methodology*, *8*(3), 517-533. https://doi.org/10.12973/ijem.8.3.517

Prodjosantoso, A. K., Hertina, A. M., & Irwanto. (2019). The Misconception diagnosis on ionic and covalent bonds concepts with three tier diagnostic test. *International Journal of Instruction, 12*(1), 1477-1488. https://doi.org/10.29333/iji.2019.12194a

Rasmitadila, R., Aliyyah, R. R., Rachmadtullah, R., Samsudin, A., Syaodih, E., Nurtanto, M., & Tambunan, A. R. S. (2020). The perceptions of primary school teachers of online learning during the COVID-19 pandemic period: A case study in Indonesia. *Journal of Ethnic and Cultural Studies, 7*(2), 90-109. https://doi.org/10.29333/ejecs/388

Reiss, M. J. (2020). Science education in the light of COVID-19: The contribution of history, philosophy and sociology of science. *Science and Education, 29*, 1079-1092. https://doi.org/10.1007/s11191-020-00143-5

Rejeb, A., Keogh, J. G., Simske, S. J., Stafford, T., & Treiblmaier, H. (2021). Potentials of blockchain technologies for supply chain collaboration: A conceptual framework. *The International Journal of Logistics Management, 32*(3), 973-994. https://doi.org/10.1108/IJLM-02-2020-0098

Resbiantoro, G., Setiani, R., & Dwikoranto. (2022). A review of misconception in physics: The diagnosis, causes, and remediation. *Journal of Turkish Science Education, 19*(2), 403-427. https://bit.ly/3ycTM9X

Roux, C., & Weyermann, C. (2020). Can forensic science learn from the COVID-19 crisis? Forensic *Science International, 316,* Article 110503. https://doi.org/10.1016/j.forsciint.2020.110503

Sadeghi, M. (2019). A shift from classroom to distance learning: Advantages and limitations. *International Journal of Research in English Education, 4*(1), 80-88. https://doi.org/10.29252/ijree.4.1.80

Sahin, D., & Yilmaz, R. M. (2020). The effect of augmented reality technology on middle school students' achievements and attitudes towards science education. *Computers and Education, 144*, Article 103710. https://doi.org/10.1016/j.compedu.2019.103710

Saputra, O., Setiawan, A., & Rusdiana, D. (2019). Identification of student misconception about static fluid. *Journal of Physics: Conference Series, 1157*(3), Article 032069. https://doi.org/10.1088/1742-6596/1157/3/032069

Savoia, M., Stefanovic, M., & Fragassa, C. (2016). Merging technical competences and human resources with the aim at contributing to transform the adriatic area in a stable hub for a sustainable technological development. *International Journal for Quality Research, 10*(1), 1-16. https://ijqr.net/journal/v10-n1/0.pdf

Schildkamp, K. (2019). Data-based decision-making for school improvement: Research insights and gaps. *Educational Research, 61*(3), 257-273. https://doi.org/10.1080/00131881.2019.1625716

Selvaraj, A., Vishnu, R., Nithin, K. A., Benson, N., & Mathew, A. J. (2021). Effect of pandemic based online education on teaching and learning system. *International Journal of Educational Development, 85*, Article 102444. https://doi.org/10.1016/j.ijedudev.2021.102444

Sghir, N., Adadi, A., & Lahmer, M. (2023). Recent advances in predictive learning analytics: A decade systematic review (2012-2022). *Education and Information Technologies, 28*, 8299-8333. https://doi.org/10.1007/s10639-022-11536-0

Shah, R. K. (2019). Effective constructivist teaching learning in the classroom. *Shanlax International Journal of Education, 7*(4), 1-13. https://doi.org/10.34293/education.v7i4.600

Siahaan, E. Y. S., Muhammad, I., Dasari, D., & Maharani, S. (2023). Research on critical thinking of pre-service mathematics education teachers in Indonesia (2015-2023): A bibliometric review. *Jurnal Math Educator Nusantara: Wahana Publikasi Karya Tulis Ilmiah Di Bidang Pendidikan Matematika, 9*(1), 34-50. https://doi.org/10.29407/jmen.v9i1.19734

Sigala, M. (2020). Tourism and COVID-19: Impacts and implications for advancing and resetting industry and research. *Journal of Business Research, 117,* 312-321. https://doi.org/10.1016/j.jbusres.2020.06.015

Singh, V., & Thurman, A. (2019). How many ways can we define online learning? A systematic literature review of definitions of online learning (1988-2018). *American Journal of Distance Education, 33*(4), 289-306. https://doi.org/10.1080/08923647.2019.1663082

Soeharto, S., Csapó, B., Sarimanah, E., Dewi, F. I., & Sabri, T. (2019). A review of students' common misconceptions in science and their diagnostic assessment tools. *Jurnal Pendidikan IPA Indonesia, 8*(2), 247-266. https://doi.org/10.15294/jpii.v8i2.18649

Sood, S. K., Kumar, N., & Saini, M. (2021). Scientometric analysis of literature on distributed vehicular networks: VOSViewer visualization techniques. *Artificial Intelligence Review, 54,* 6309-6341. https://doi.org/10.1007/s10462-021-09980-4

Stern, F., Kampourakis, K., Delaval, M., & Müller, A. (2020). Development and validation of a questionnaire measuring secondary students' genetic essentialism and teleology (GET) conceptions. *International Journal of Science Education, 42*(2), 218-252. https://doi.org/10.1080/09500693.2019.1707905

Sumardi, L., Rohman, A., & Wahyudiati, D. (2020). Does the Teaching and Learning Process in Primary Schools Correspond to the Characteristics of the 21st Century Learning? *International Journal of Instruction, 13*(3), 357-370. https://doi.org/10.29333/iji.2020.13325a

Suprapto, N. (2020). Do we experience misconceptions?: An ontological review of misconceptions in science. *Studies in Philosophy of Science and Education, 1*(2), 50-55. https://doi.org/10.46627/sipose.v1i2.24

Tang, X., Yin, Y., Lin, Q., Hadad, R., & Zhai, X. (2020). Assessing computational thinking: A systematic review of empirical studies. *Computers and Education, 148*, Article 103798. https://doi.org/10.1016/j.compedu.2019.103798

Thacker, I., Sinatra, G. M., Muis, K. R., Danielson, R. W., Pekrun, R., Winne, P. H., & Chevrier, M. (2020). Using persuasive refutation texts to prompt attitudinal and conceptual change. *Journal of Educational Psychology, 112*(6), 1085-1099. https://doi.org/10.1037/edu0000434

Thees, M., Kapp, S., Strzys, M. P., Beil, F., Lukowicz, P., & Kuhn, J. (2020). Effects of augmented reality on learning and cognitive load in university physics laboratory courses. *Computers in Human Behavior, 108*, Article 106316. https://doi.org/10.1016/j.chb.2020.106316

Toader, T., Safta, M., Titirişcă, C., & Firtescu, B. (2021). Effects of digitalisation on higher education in a sustainable development framework—Online learning challenges during the COVID-19 pandemic. *Sustainability, 13*(11), Article 6444. https://doi.org/10.3390/su13116444

Tumanggor, A. M. R., Supahar, Kuswanto, H., & Ringo, E. S. (2020). Using four-tier diagnostic test instruments to detect physics teacher candidates' misconceptions: Case of mechanical wave concepts. *Journal of Physics: Conference Series, 1440*, Article 12059. https://doi.org/10.1088/1742-6596/1440/1/012059

Turan, Z., & Atila, G. (2021). Augmented reality technology in science education for students with specific learning difficulties: Its effect on students' learning and views. *Research in Science & Technological Education, 3*9(4), 506-524. https://doi.org/10.1080/02635143.2021.1901682

van Driel, J. H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *35*(6), 673-695. https://doi.org/10.1002/(SICI)1098-2736(199808)35:6%3C673::AID-TEA5%3E3.0.CO;2-J

Vaughn, A. R., Brown, R. D., & Johnson, M. L. (2020). Understanding conceptual change and science learning through educational neuroscience. *Mind, Brain, and Education*, *14*(2), 82-93. https://doi.org/10.1111/mbe.12237

Vrontis, D., Makrides, A., Christofi, M., & Thrassou, A. (2021). Social media influencer marketing: A systematic review, integrative framework and future research agenda. *International Journal of Consumer Studies, 45*(4), 617-644. https://doi.org/10.1111/ijcs.12647

Washburn, A. N., & Skitka, L. J. (2018). Science denial across the political divide: Liberals and conservatives are similarly motivated to deny attitude-inconsistent science. *Social Psychological and Personality Science, 9*(8), 972-980. https://doi.org/10.1177/1948550617731500

Wen, H., Khan, F., Amin, M. T., & Halim, S. Z. (2022). Myths and misconceptions of data-driven methods: Applications to process safety analysis. *Computers and Chemical Engineering, 158,* Article 107639. https://doi.org/10.1016/j.compchemeng.2021.107639

Yang, D.-C., & Sianturi, I. A. J. (2021). Sixth grade students' performance, misconception, and confidence on a three-tier number sense test. *International Journal of Science and Mathematics Education, 19*, 355-375. https://doi.org/10.1007/s10763-020-10051-3

Yang, K.-H., & Chen, H.-H. (2023). What increases learning retention: Employing the prediction-observation-explanation learning strategy in digital game-based learning. *Interactive Learning Environments, 31*(6), 3898-3913. https://doi.org/10.1080/10494820.2021.1944219

Yang, K.-H., & Lu, B.-C. (2021). Towards the successful game-based learning: Detection and feedback to misconceptions is the key. *Computers and Education, 160,* Article 104033. https://doi.org/10.1016/j.compedu.2020.104033

Yolanda, Y. (2020). Development of contextual-based teaching materials in the course of magnetic electricity. *Thabiea: Journal of Natural Science Teaching, 3*(1), 59-69. https://doi.org/10.21043/thabiea.v3i1.6616

Yu, Z., & Li, M. (2022). A bibliometric analysis of Community of Inquiry in online learning contexts over twenty-five years. *Education and Information Technologies, 27*, 11669-11688. https://doi.org/10.1007/s10639-022-11081-w

Zhou, K., Liu, T., & Zhou, L. (2015). Industry 4.0: Towards future industrial opportunities and challenges. In *2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)* (pp. 2147-2152). IEEE. https://doi.org/10.1109/FSKD.2015.7382284

Zhou, X., Tang, L., Lin, D., & Han, W. (2020). Virtual & augmented reality for biological microscope in experiment education. *Virtual Reality and Intelligent Hardware, 2*(4), 316-329. https://doi.org/10.1016/j.vrih.2020.07.004

Zidny, R., Sjöström, J., & Eilks, I. (2020). A Multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. *Science and Education, 29*, 145-185. https://doi.org/10.1007/s11191-019-00100-x