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Review Paper

Review of Trends in Peer Instruction: Bibliometric Mapping Analysis and Systematic Review

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ABSTRACT

This research aims to reveal the trend in peer instruction that many researchers around the world have been working on for over 20 years. In this context, 58 papers published in journals indexed in SSCI were examined in terms of different variables (e.g., research methods, courses, and response technologies). The bibliometric results showed that the most used keyword and the most used word in the abstract sections of the studies was peer instruction. Systematic review results revealed that the continent and country with the most studies among 17 countries in four continents is North America and the USA, respectively. Moreover, the majority of studies were published in 2016. It was also found that studies are generally carried out with numerical courses such as physics, chemistry, and computer science. Other findings provided from the researches were discussed in detail, and various suggestions were made for teachers and researchers in line with the findings obtained from the study.

INTRODUCTION

Peer instruction (PI) is a student-centered active learning approach developed by the physics education research group (Eric Mazur and his colleagues) at Harvard University in the 1990s (Brown, 2020; Liao et al., 2019; Wang & Murota, 2016; Zhang, Ding, & Mazur, 2017). Mazur stated that it is very difficult to maintain students' attention throughout the whole course, especially in large classes, and that ensuring student interaction and focusing students' attention on the underlying concepts during the course are the main objectives of the PI method (Mazur, 1997). Although there are differences in studies by different researchers (e.g., Kalman et al., 2010; Michinov et al., 2015; Zingaro & Porter, 2014), Mazur (1997) described the process of the classic PI model as "1) Question posed, 2) Students given time to think, 3) Students record individual answers (optional), 4) Students convince their neighbors (peer instruction), 5) Students record revised answers (optional), 6) Feedback to teacher: Tally of answers, and 7) Explanation of correct answer". In other words, it can be said that a classic sequence for PI starts with posing the question and continues with the first individual voting, see the answers, peer discussion, and second individual voting. Furthermore, students may be asked to write explanations about their answers and report their confidence level (e.g., Chou & Lin, 2015; Tullis & Goldstone, 2020). The results of the study conducted by Dancy and Henderson (2010) with the 722 physics faculty showed that the most widely known and the most highly used strategy was PI and, nearly half of all the participants reporting that they used PI also indicated that they did not use it in a way that is consistent with the classic PI sequence.

In the PI process, a blackboard, a projector, or oral form can be posed questions to students (Chou & Lin, 2015). Clickers (e.g., Pearson, 2019), flashcards (e.g., Gok, 2015), and phones, tablets, or laptops (e.g., Zou & Xie, 2019), etc. can be used to get students' responses, depending on the learning environment and the purpose of the study. Watkins and Mazur (2010, pp. 41) stated that "the quality of student discussion and learning in a PI classroom depends on the quality of the ConcepTests". Moreover, the effectiveness of the ConcepTests (conceptual multiple-choice questions) requires students to think about the higher-level concepts in the questions and not be able to solve the questions simply by recalling something. Although multiple-choice questions are commonly used in the PI, open-ended questions (e.g., Wang & Murota, 2016), short-answer (also referred to as free-text questions) questions (e.g., Pearson, 2017), and true/false (two possible answers) questions (e.g., Perez et al., 2010) can also be used.

When the literature is examined, it is seen that such as using isomorphic questions (e.g., Porter, et al., 2011; Zingaro & Porter, 2014), discussion partner assignment, and using accountability scoring mechanisms (Chou & Lin, 2015), the effect of not showing /showing the bar graph of students' first voting before the discussion (e.g., Perez et al., 2010), live responses versus responses only available after the poll had closed (Pearson, 2019), and giving students points for participation regardless of whether their answers are correct (Hubbard & Couch, 2018), etc. many innovative approaches can be applied to support students' learning, active participation, academic engagement, motivation, etc. in the PI process. Furthermore, the PI method, which is becoming widespread with each passing day, is also used in many different courses related to biology (e.g., Hubbard & Couch, 2018), chemistry (e.g., Yıldırım &

Canpolat, 2019), computer science (e.g., Adawi et al., 2016), economics (e.g., Ghosh & Renna, 2009), mathematics (e.g., Olpak et al., 2018), medical science (e.g., Versteeg et al., 2019), and science (e.g., Jones et al., 2012), etc. from different disciplines. Moreover, in the study conducted by Henderson (2019), it was stated that PI is one of the most popular research-based instructional practices in STEM education. However, to date, no study has examined the recent trends in PI. In this context, unlike previous research (e.g. Balta et al., 2017; Vickrey et al., 2015), this research aimed to reveal the trends in PI. For this purpose, answers to the following questions were sought:

- What were the most frequently used keywords in the reviewed articles?
- What were the most frequently used words in the abstract sections of in the reviewed articles?
- Where, when, and by whom were the reviewed articles published?
- What was the geographical distribution of the reviewed articles?
- What was the distribution of the reviewed articles according to the research methods used?
- What was the distribution of the reviewed articles according to the course studied?
- What types of participants were selected in the reviewed articles?
- What types of response technologies were selected in the reviewed articles?

METHOD

Selection of Studies

In studies aiming to reveal trends in a specific research area, many different criteria can be taken into account in the selection of relevant studies (e.g., Akçayır & Akçayır, 2018; Kim & Gurvitch, 2020). In this context, the following search criteria were applied in the advanced search section of the Web of Science (WOS) Core Collection database on February 8th, 2021 (TI = "peer instruction" or AK = "peer instruction" or AB = "peer instruction", Language: English, Document Types: Article or Review, Timespan: 1997-2020, Indexes: SSCI). Thus, a total of 101 papers with the words Peer Instruction, Peer instruction or peer instruction, etc. in the title/keywords/abstract, written in English and published in journals indexed SSCI between 1997-2020 were found. However, the full text of 8 of these papers could not be accessed and downloaded. The full text of the remaining 93 studies was downloaded to a computer in electronic format. The downloaded papers were examined in detail by considering the criteria specified in Table 1 in terms of their suitability for this study. As seen in Figure 1, 58 articles related to the purpose of the present study were obtained as a result of the examination made by the researchers.

Table 1. Article selection criteria

Inclusion Criteria	Exclusion Criteria
Peer instruction is the primary content focus	Research in different contexts despite meeting the search criteria
Papers should be listed in WOS, indexed in SSCI, and written in English	Studies that were editorials and article reviews

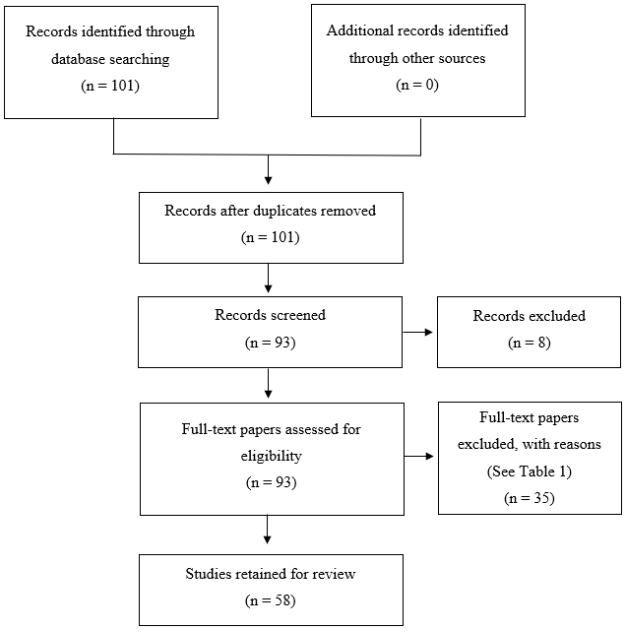

Figure 1. Search strategy

The search results completed in the advanced search section of WOS were refined to show 58 papers to be studied within the scope of the research, on the date of February 8th of 2021. The bibliometric information for these 58 papers was downloaded by selecting the 'full record and cited references' option and saved as a tab-delimited (Win) text file. The text file obtained from WOS was

transformed to a Microsoft Excel format. Considering the BMA to be made using the VOSviewer software tool, several identifiers of the articles (e.g., Year Published, Author Keywords, and Abstract) were carefully examined and necessary manual corrections applied. The data in the Microsoft Excel file were transferred back to a tab-delimited (Win) text file for BMA using the VOSviewer. Besides, the citation reports related to 58 studies were downloaded as a Microsoft Excel file. Furthermore, the Microsoft Excel files for 'citation reports' and 'full record and cited references' were combined into a single Microsoft Excel file, and the final dataset was obtained (58 records).

Data Analysis

In the current study, the publication classification form (PCF) similar to previous studies (e.g., Akçayır & Akçayır, 2016; Crompton & Burke, 2018) was used by researchers after some arrangements were applied. In addition to the dataset, column headings in the PCF were added, and the relevant fields were filled in for each paper by the researchers. The data obtained from the PCF were analyzed using descriptive statistics, and the VOSviewer was used for the analysis of the most used keywords and the most used words in abstract sections of the reviewed papers.

RESULTS

Most Frequently Used Keywords

Since 23 (39.66%) out of 58 papers did not have keywords, these analyzes were made according to the data in the studies where keywords entries were made. As seen in Figure 2, the results showed that the most used keywords are peer instruction (f=27), collaborative learning (f=7), clickers (f=6), active learning (f=5), and higher education (f=5), respectively.

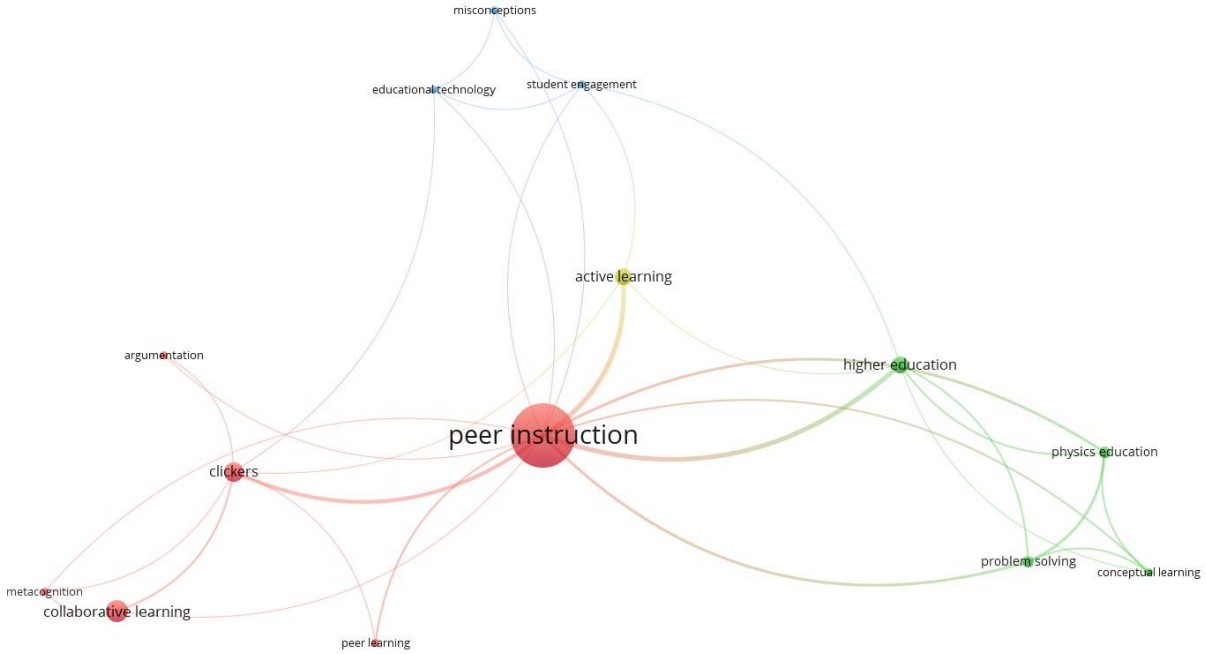

Figure 2. The most used keywords

Most Used Words in Abstract Sections

As seen in Figure 3, the results showed that the most used words in the abstract sections of the reviewed papers are peer instruction (f=50), question (f=31), group (f=24), effect (f=16), and instructor (f=15), respectively.

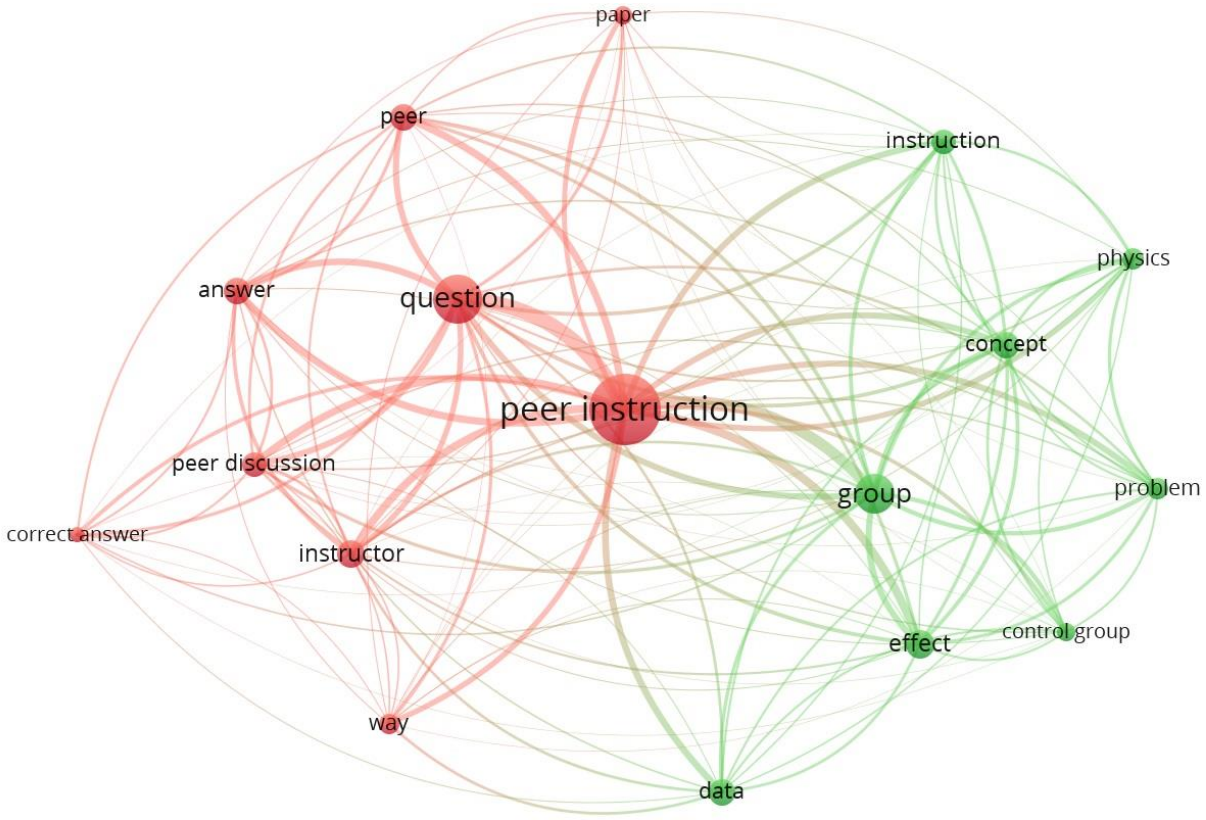

Figure 3. The most used words in abstract sections

Authors and Publication Years

58 articles reviewed within the scope of this research were produced by 125 authors from 17 countries. Besides the results also revealed that 104 authors took part in one article, 17 authors in two articles, one author in three articles, two authors in four articles, and one author in five articles. According to Table 2, the highest number of articles were published in 2016 (*n*=9), and most of the published articles were conducted by two (*n*=16) or three (*n*=16) authors. Although searches have been made since 1997, no articles that meet the criteria have been published 1997-2003, and there has been uninterrupted publication since 2009.

Table 2. The distribution of articles in terms of publication years and number of authors

Publication year	Number of authors						Total
	1	2	3	4	5	6	
2003		1					1
2009		2	1				3
2010	1	1	2			1	5
2011	1	1					2
2012	1	1	1				3
2013	1						1
2014	1	1		1	2		5
2015	1	1	1	1	3		7
2016		1	6	2			9
2017	2		2	1			5
2018	2	3	1				6
2019	2	3	1	1		1	8
2020	1	1	1				3
Total	13	16	16	6	5	2	58

Journals

The 58 papers reviewed in this study were published in 32 journals in total, only one article was published in 22 of these journals. Furthermore, two papers in four journals, three papers in four journals, and eight papers in two journals were published. The journals

with the highest number of articles published were Physical Review Physics Education Research (8 documents) and Physical Review Special Topics - Physics Education Research (8 documents).

Geographical Distribution

Geographically, the studies were conducted in 17 countries on four continents (see Figure 4). In meta-analysis or literature review studies conducted by more than one researcher, the country of the first author was classified as the country where the study was conducted. Similarly, if the country in which the study was conducted was not clearly stated, the country of the first author was used. Finally, Turkey and Kazakhstan, even though the territory in both Asia and Europe, studies in these countries are classified as Asia. The continent with the highest number of studies in North America (*n*=25), followed by Asia (*n*=17), Europe (*n*=15), and South America (*n*=1). Also, among the countries, the USA was the country with the highest number of studies (*n*=20), followed by Turkey (*n*=7), the UK (*n*=6), and France (*n*=5).

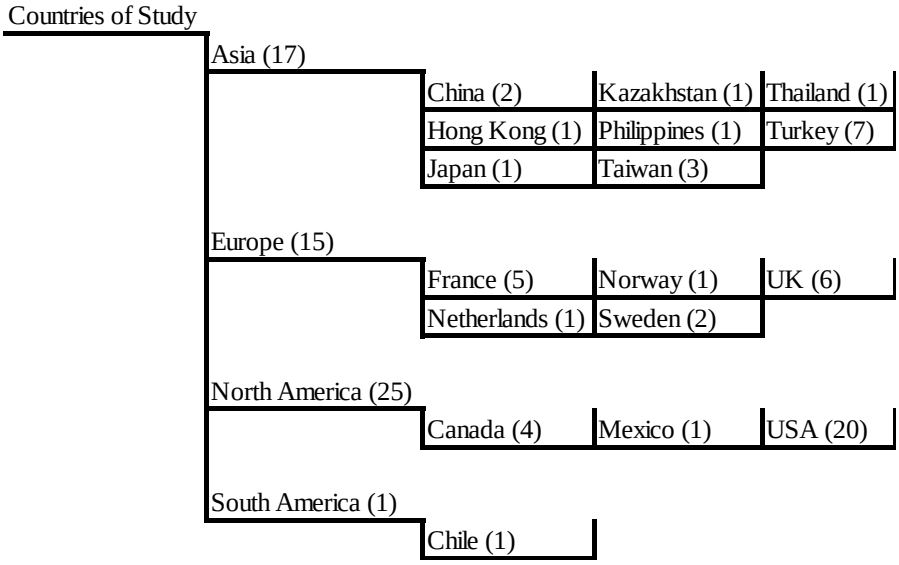

Figure 4. Geographical distribution

Research Method

As seen in Table 3, quantitative research methods (*n*=32) were the most common research method, followed by mixed-method studies (*n*=15), qualitative studies (*n*=8), and other research methods (literature review, meta-analysis, or theoretical studies) studies (*n*=3).

Course

In the reviewed papers; it is seen that (see Table 3) studies are generally carried out with numerical courses such as physics (*n*=30), chemistry (*n*=7), and computer science (*n*=5). While creating the frequencies as seen in Table 3 for the reviewed papers; if more than one course in the same discipline (e.g., Liao et al., 2019) was carried out in a study, the frequency of the relevant discipline was increased by one. However, if more than one course from different disciplines was studied in a study (e.g., Aricò & Lancaster, 2018), the frequency of all related disciplines was increased by one. The course in which the research was conducted was classified as 'Not specified' if it was unspecified or undetermined. Finally, in some studies (Hung, 2017; Zou & Xie, 2019), the courses classified as 'Languages' (English writing course, and learning English as a foreign language) are related to English.

Type of Participant

Participants in the studies were classified similarly to earlier review studies (e.g., Akçayır & Akçayır, 2016). However, since it is not possible to make a type of participants classification (e.g., unspecified or undetermined) for some papers (e.g., Knight & Brame, 2018), 'Not specified' has been added to the options. Moreover, for studies with more than one type of participant (e.g., Nitta, 2010), the 'Mixed' option was added. As seen in Table 3, the majority of the participants were higher education students (77.59%) in the reviewed articles.

Response Technology

In the current study, the technology used in the question and answer process of PI was called response technology. When the literature is examined, it is seen that the technologies used for this purpose are named in different ways in different studies. For example, different terms such as electronic voting systems (e.g., Wood et al., 2016), electronic classroom response system (e.g., Turpen & Finkelstein, 2010), classroom response system (e.g., Zhang et al., 2017), or student response systems (e.g., Hung, 2017)

can be preferred instead of clickers. As indicated in Table 3, clickers (*n*=33) were the most common response technology in the reviewed papers.

Table 3. Research method, course, type of participant, and response technology

#	Number of articles
Research methods	
Quantitative	32
Qualitative	8
Mixed	15
Other	3
Course	
Biology	2
Chemistry	7
Computer science	5
Economics	3
Languages	2
Mathematics	2
Medical science	2
Not specified	3
Physics	30
Psychology	2
Science	1
Type of participant	
Faculty	3
Higher education	45
K-12	5
Mixed	2
Not specified	3
Response technology	
Clickers	33
Flashcards or hands-on	7
Not specified	7
Paper-pencil	5
Phones, tablets, or laptops, etc.	8

DISCUSSION

This study aimed to reveal recent trends in the PI using BMA and systematic review, and 58 studies were examined. The BMA results indicated that the most used keywords in the reviewed papers were: peer instruction, collaborative learning, clickers, active learning, and higher education. These results showed that the reviewed studies are based on the PI and its key points. Furthermore, it can be said that these results are consistent with the other findings of the current study. Because the findings of the present research showed that clickers are the most common response technologies and the majority of the participants were higher education students. Moreover, considering that PI is an active learning approach that supports collaborative learning (Balta et al., 2017; Michinov et al., 2015), it can be said that this also supports the findings on keywords. Besides, the most used words in the studies' abstract sections were peer instruction, question, group, effect, and instructor which also support these findings.

Considering the number of authors of the reviewed studies, since all but 13 (22.41%) include more than one author, this finding suggests a trend towards more collaborative work amongst researchers. Looking at the publication year of each article, it was seen that a total of 43 articles (74.14%) were published in the last 7 years (since 2014), and that interest in the PI has increased in recent years. This may be due to the fact that technologies that can be used in the PI method in parallel with the development of communication technologies are cheaper and easily accessible. For example, in the study conducted by Chien et al. (2015), it was stated that the use of clickers, which are frequently used in the question and answer process of PI, is increasingly widespread and it is estimated that millions of clickers are sold to schools around the world each year. Furthermore, the results showed that the most preferred journals were Physical Review Physics Education Research and Physical Review Special Topics - Physics Education Research. The publication of more articles in these journals related to physics education research may be due to the fact that PI is developed by the physics education research group (e.g., Zhang et al., 2017).

The results revealed that the North America continent has dominated the findings with the highest number of research. Moreover, the USA was the country with the highest number of articles. This may be because the PI method was first applied at a university in the USA (e.g., Brown, 2020). In addition, as indicated in **Hata! Başvuru kaynağı bulunamadı.**, the three countries (USA, UK, and Canada) where more than half of the reviewed studies (51.72%) were conducted are English-speaking countries. However, it should be taken into consideration that all of the papers included in this review were written in the English language and that studies published in journals, not SSCI-indexed or written in languages other than English may have been conducted. Although the results of the present study indicate that research on PI is predominantly concentrated in the USA, it seems that there is interest in PI in other countries (e.g., Turkey, the UK) as well. It also appears that interest in PI has increased in recent years and researchers often tend to work together. In this context, the researchers from different cultures, taking into account the various individual differences of the learners, can provide more in-depth knowledge about PI by conducting new studies.

The results showed that the most preferred research method among the research methods was the quantitative research method, and 68.97% of the reviewed articles were conducted using a single research method (quantitative or qualitative). This may be due to the fact that mixed-method studies are more expensive than the single-method approach in terms of time, money, and energy (e.g., Abowitz & Toole, 2010). However, mixed-method researches can also make it easier to answer more complex research questions, as it allows combining research styles that balance strengths and weaknesses (Abowitz & Toole, 2010; Johnson & Onwuegbuzie, 2004). Moreover, reviewed studies are generally carried out in numerical courses such as physics (e.g., Zu, Munsell, & Rebello, 2019), chemistry (e.g., Pearson, 2019), and computer science (e.g., Adawi et al., 2016), and that these findings are consistent with earlier studies (e.g., Balta et al., 2017). In the study conducted by Liao et al. (2019), in a way to support these findings, it was stated that the PI method was invented for introductory physics courses and then adopted for computer science. In this context, conducting new research using mixed-method design in courses in different disciplines in future research can contribute to the literature on the PI.

The results also showed that the majority of the studies' participants were higher education students, which is consistent with an earlier meta-analysis study conducted by Balta et al. (2017). This may be due to the development of the PI method through studies conducted at a higher education institution (e.g., Zhang et al., 2017), or from researchers' choice for convenience or purposeful sampling methods. Finally, it was determined that the majority of response technologies in the reviewed papers were clickers. Moreover, in a meta-analytic study conducted by Chien et al. (2016) on clickers, it has been stated that the educational potential of clickers is of great interest by researchers and educators in various disciplines, and it can be said that tens of thousands of courses around the world are being conducted with the addition of clickers. In this context, it is recommended to conduct new researches on the effective use of different response technologies with students at different educational levels in future studies.

LIMITATIONS

Whilst the present study reviewed papers written in the English language and published in SSCI-indexed journals in the WOS, future studies could review other document types (e.g., dissertations), indexes other than SSCI in the WOS (e.g., ESCI), indexed in different databases (e.g., ERIC), or written in other languages. Thus, the different datasets could be obtained and various trends related to the PI thereby revealed.

CONCLUSIONS

In the present study, 58 papers published in SSCI-indexed journals related to the PI were analyzed in terms of different variables. Although the history of the PI method dates back to the 1990s, there has been an increase in the number of studies conducted in recent years. In this context, this study revealed useful results and provided an up-to-date evaluation to help researchers gain a holistic understanding of the importance of the PI, and also to understand the current research gaps in the literature.

Ethics and Consent: Ethics committee approval is not required as it does not involve clinical researches on humans as well as it does not contain Retrospective studies in accordance with the Law on Protection of Personal Data.

REFERENCES

Abowitz, D. A., & Toole, T. M. (2010). Mixed method research: Fundamental issues of design, validity, and reliability in construction research. *Journal of Construction Engineering and Management*, *136*(1), 108–116. https://doi.org/10.1061/(asce)co.1943-7862.0000026

Adawi, T., Burden, H., Olsson, D., & Mattiasson, R. (2016). Characterizing software engineering students' discussions during peer instruction: Opportunities for learning and implications for teaching. *International Journal of Engineering Education*, *32*(2), 927–936.

Akçayır, G., & Akçayır, M. (2016). Research trends in social network sites' educational use: A review of publications in all SSCI journals to 2015. *Review of Education*, *4*(3), 293–319.

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. *Computers & Education*, *126*, 334–345. https://doi.org/https://doi.org/10.1016/j.compedu.2018.07.021

Aricò, F. R., & Lancaster, S. J. (2018). Facilitating active learning and enhancing student self-assessment skills. *International*

Review of Economics Education, *29*, 6–13. https://doi.org/10.1016/j.iree.2018.06.002

Balta, N., Michinov, N., Balyimez, S., & Ayaz, M. F. (2017). A meta-analysis of the effect of peer instruction on learning gain: Identification of informational and cultural moderators. *International Journal of Educational Research*, *86*, 66–77. https://doi.org/10.1016/j.ijer.2017.08.009

Brown, M. (2020). Seeing students at scale: How faculty in large lecture courses act upon learning analytics dashboard data. *Teaching in Higher Education*, *25*(4), 384–400. https://doi.org/10.1080/13562517.2019.1698540

Chien, Y.-T., Chang, Y.-H., & Chang, C.-Y. (2016). Do we click in the right way? A meta-analytic review of clicker-integrated instruction. *Educational Research Review*, *17*, 1–18. https://doi.org/10.1016/j.edurev.2015.10.003

Chien, Y.-T., Lee, Y.-H., Li, T.-Y., & Chang, C.-Y. (2015). Examining the effects of displaying clicker voting results on high school students' voting behaviors, discussion processes, and learning outcomes. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(5), 1089–1104.

Chou, C. Y., & Lin, P. H. (2015). Promoting discussion in peer instruction: Discussion partner assignment and accountability scoring mechanisms. *British Journal of Educational Technology*, *46*(4), 839–847.

Crompton, H., & Burke, D. (2018). The use of mobile learning in higher education: A systematic review. *Computers & Education*, *123*, 53–64.

Dancy, M., & Henderson, C. (2010). Pedagogical practices and instructional change of physics faculty. *American Journal of Physics*, *78*(10), 1056–1063.

Ghosh, S., & Renna, F. (2009). Using electronic response systems in economics classes. *Journal of Economic Education*, *40*(4), 354–365. https://doi.org/10.1080/00220480903297651

Gok, T. (2015). An investigation of students' performance after peer instruction with stepwise problem-solving strategies. *International Journal of Science and Mathematics Education*, *13*(3), 561–582.

Henderson, J. B. (2019). Beyond "active learning": How the ICAP framework permits more acute examination of the popular peer instruction pedagogy. *Harvard Educational Review*, *89*(4), 611–634.

Hubbard, J. K., & Couch, B. A. (2018). The positive effect of in-class clicker questions on later exams depends on initial student performance level but not question format. *Computers & Education*, *120*, 1–12. https://doi.org/10.1016/j.compedu.2018.01.008

Hung, H.-T. (2017). The integration of a student response system in flipped classrooms. *Language Learning & Technology*, *21*(1), 16–27.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14–26. https://doi.org/10.3102/0013189X033007014

Jones, M. E., Antonenko, P. D., & Greenwood, C. M. (2012). The impact of collaborative and individualized student response system strategies on learner motivation, metacognition, and knowledge transfer. *Journal of Computer Assisted Learning*, *28*(5), 477–487. https://doi.org/10.1111/j.1365-2729.2011.00470.x

Kalman, C. S., Milner-Bolotin, M., & Antimirova, T. (2010). Comparison of the effectiveness of collaborative groups and peer instruction in a large introductory physics course for science majors. *Canadian Journal of Physics*, *88*(5), 325–332.

Kim, G. C., & Gurvitch, R. (2020). Online education research adopting the community of inquiry framework: A systematic review. *Quest*, *72*(4), 395–409. https://doi.org/10.1080/00336297.2020.1761843

Knight, J. K., & Brame, C. J. (2018). Peer instruction. *CBE-Life Sciences Education*, *17*(2), 1–4. https://doi.org/10.1187/cbe.18-02-0025

Liao, S. N., Zingaro, D., Thai, K., Alvarado, C., Griswold, W. G., & Porter, L. (2019). A robust machine learning technique to predict low-performing students. *ACM Transactions on Computing Education*, *19*(3), 1–19. https://doi.org/10.1145/3277569

Mazur, E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, New Jersey: Prentice-Hall.

Michinov, N., Morice, J., & Ferrières, V. (2015). A step further in peer instruction: Using the Stepladder technique to improve learning. *Computers & Education*, *91*, 1–13. https://doi.org/10.1016/j.compedu.2015.09.007

Nitta, H. (2010). Mathematical theory of peer-instruction dynamics. *Physical Review Special Topics - Physics Education Research*, *6*(2), 6–9. https://doi.org/10.1103/PhysRevSTPER.6.020105

Olpak, Y. Z., Baltacı, S., & Arıcan, M. (2018). Investigating the effects of peer instruction on preservice mathematics teachers' achievements in statistics and probability. *Education and Information Technologies*, *23*(6), 2323–2340. https://doi.org/10.1007/s10639-018-9717-3

Pearson, R. J. (2017). Tailoring clicker technology to problem-based Learning: What's the best approach? *Journal of Chemical Education*, *94*(12), 1866–1872. https://doi.org/10.1021/acs.jchemed.7b00270

Pearson, R. J. (2019). Exploring peer instruction: Should cohort clicker responses appear during or after polling? *Journal of Chemical Education*, *96*, 873–879. https://doi.org/10.1021/acs.jchemed.9b00035

Perez, K. E., Strauss, E. A., Downey, N., Galbraith, A., Jeanne, R., & Cooper, S. (2010). Does displaying the class results affect student discussion during peer instruction? *CBE-Life Sciences Education*, *9*(2), 133–140. https://doi.org/10.1187/cbe.09–11–0080

Porter, L., Bailey Lee, C., Simon, B., & Zingaro, D. (2011). Peer instruction: Do students really learn from peer discussion in computing? In *Proceedings of the seventh international workshop on computing education research* (pp. 45–52) ACM.

Tullis, J. G., & Goldstone, R. L. (2020). Why does peer instruction benefit student learning? *Cognitive Research: Principles and Implications*, *5*. https://doi.org/10.1186/s41235-020-00218-5

Turpen, C., & Finkelstein, N. D. (2010). The construction of different classroom norms during peer instruction: Students perceive differences. *Physical Review Special Topics - Physics Education Research*, *6*(2). https://doi.org/10.1103/PhysRevSTPER.6.020123

Versteeg, M., van Blankenstein, F. M., Putter, H., & Steendijk, P. (2019). Peer instruction improves comprehension and transfer of

physiological concepts: A randomized comparison with self-explanation. *Advances in Health Sciences Education*, *24*(1), 151–165. https://doi.org/10.1007/s10459-018-9858-6

Vickrey, T., Rosploch, K., Rahmanian, R., Pilarz, M., & Stains, M. (2015). Research-based implementation of peer instruction: A literature review. *CBE-Life Sciences Education*, *14*, 1–11.

Wang, S., & Murota, M. (2016). Possibilities and limitations of integrating peer instruction into technical creativity education. *Instructional Science*, *44*(6), 501–525.

Watkins, J., & Mazur, E. (2010). Just-in-time teaching and peer instruction. In S. Simkins & M. H. Maier (Eds.), Just in time teaching: Across the disciplines, across the academy (pp. 39–62). Sterling, VA: Stylus Publishing.

Wood, A. K., Galloway, R. K., Donnelly, R., & Hardy, J. (2016). Characterizing interactive engagement activities in a flipped introductory physics class. *Physical Review Physics Education Research*, *12*(1). https://doi.org/10.1103/PhysRevPhysEducRes.12.010140

Yıldırım, T., & Canpolat, N. (2019). An investigation of the effectiveness of the peer instruction method on teaching about solutions at the high-school level. *Education and Science*, *44*, 127–147. https://doi.org/10.15390/EB.2019.7966

Zhang, P., Ding, L., & Mazur, E. (2017). Peer instruction in introductory physics: A method to bring about positive changes in students' attitudes and beliefs. *Physical Review Physics Education Research*, *13*(1). https://doi.org/10.1103/PhysRevPhysEducRes.13.010104

Zingaro, D., & Porter, L. (2014). Peer instruction in computing: The value of instructor intervention. *Computers & Education*, *71*, 87–96. https://doi.org/10.1016/j.compedu.2013.09.015

Zou, D., & Xie, H. (2019). Flipping an English writing class with technology-enhanced just-in-time teaching and peer instruction. *Interactive Learning Environments*, *27*(8), 1127–1142. https://doi.org/10.1080/10494820.2018.1495654

Zu, T., Munsell, J., & Rebello, N. S. (2019). Comparing retrieval-based practice and peer instruction in physics learning. *Physical Review Physics Education Research*, *15*(1). https://doi.org/10.1103/PhysRevPhysEducRes.15.010105