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Type of Active Learning Implementation in Science Education: A Systematic Review

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Abstrak

Melibatkan siswa dalam pembelajaran aktif dikaitkan dengan hasil belajar yang positif. Meskipun terdapat bukti yang mendukung hasil pembelajaran positif dari pembelajaran aktif, penerapan pembelajaran aktif berjalan lambat. Banyak peneliti pendidikan telah mendokumentasikan penerapan pembelajaran aktif. Namun, belum ada penelitian yang menganalisis secara sistematis penelitian-penelitian tersebut mengenai jenis penerapan pembelajaran aktif dalam pendidikan sains. Kajian analisis tinjauan sistematik ini dilakukan untuk mengkaji tipe penerapan pembelajaran aktif dalam pendidikan sains. Kriteria utama pemilihan artikel adalah pelaksanaan pembelajaran aktif bidang pendidikan sains dengan periode berkisar antara tahun 2012 hingga 2022 dari database ternama internasional. Diperoleh 20 artikel yang sesuai kriteria dengan menggunakan kata kunci Active Learning. Kajian difokuskan pada mata kuliah, jenis pembelajaran aktif, tujuan, metode, sampel, dan alat pengumpulan data. Hasilnya menunjukkan bahwa mata kuliah yang paling banyak dipelajari adalah kimia interdisipliner. Jenis pembelajaran aktif berkode Tidak berlaku, Lainnya, Pembelajaran hibrid, Kerja kelompok, Pembelajaran berbasis online, Pembelajaran Langsung, dan Inkuiri. Artikel bertujuan untuk menyelidiki efek pembelajaran aktif menggunakan metode kuantitatif. Sampel mahasiswa sarjana memperkaya penelitian ini, dengan data yang dikumpulkan melalui survei dan deskripsi. Temuan ini dapat menginspirasi para pendidik sains untuk mengadopsi strategi pembelajaran aktif yang sesuai, sehingga berdampak pada prestasi siswa dalam pendidikan sains.

***Keywords**: Pembelajaran Aktif, Review Sistematis, Studi Kualitatif*

Abstract

Involving students in active learning is associated with positive learning outcomes. Despite the evidence supporting the positive learning outcomes of active learning, the adoption of active learning has been slow. Numerous education researchers have documented their application of active learning. However, there is no research yet that systematically analyzes these studies regarding the type of active learning implementation in science education. This systematic review analysis study was conducted to review the type of active learning implementation in science education. The main criteria for the selection of articles is the implementation of active learning in the field of science education with a period ranging from 2012 to 2022 from the well-known international database. There were 20 articles were obtained that fit into the criteria using the Active Learning keyword. The review was focused on the course, type of active learning, aims, method, samples, and data collection tools. The results show that the most studied course is interdisciplinary chemistry. Active learning types coded Not applicable, Others, Hybrid learning, Group work, Online-based learning, Hands-on Learning, and Inquiry. Articles aim to investigate active learning effects using quantitative methods. Undergraduate student samples enriched these studies, with data collected through surveys and descriptions. These findings can inspire science educators to adopt suitable active learning strategies, impacting students' achievements in science education.

Keywords: Active Learning, Systematic Review, Qualitative Study

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1. INTRODUCTION

The virtue of being an engaged learner is one of the most widely accepted concepts in education. Over the past fifty years, a range of educational theories have gradually presented differing viewpoints about the notion of active learning and its advantages over passive learning (Freeman et al., 2014; Patrick et al., 2016). According to previous study these theories include constructivism, experiential learning, inquiry learning, self-regulated learning, and discovery learning (Markant et al., 2016). Using a range of activities such as debates, clicker questions, group discussions, and projects, active learning strategies improve student performance and engagement in the classroom. These strategies are effective, as several studies have shown, especially for first-generation and minority students in higher education (Chi & Wylie, 2014; Eddy & Hogan, 2014).

Learning is an active process that involves the individual actively constructing meaning based on relevant prior experiences (Amin & Sukestiyarno, 2015; Magen Nagar, 2016). According to a wealth of research, active learning pedagogy and course transformation positively affect students' academic success, learning experiences, and engagement levels (McLaughlin et al., 2014). Students' learning is greatly influenced by active learning through activities, which also has a favorable impact on their mastery of the material (Celik, 2018; Theobald et al., 2020). Students might be exposed to debates, discussions, group projects, and opinion sharing through educational activities. These circumstances and activities will foster metacognitive abilities. In contrast, passive learning tends to discourage critical thinking, questioning, and constructive criticism (Abu Bakar & Ismail, 2020).

Despite the overwhelming evidence in favor of active learning, as studies that show traditional teaching techniques like lecturing continue to be used extensively (Freeman et al., 2014), and there are still issues with the adoption rates of active learning (Hora & Ferrare, 2013; Stains et al., 2018). These low adoption rates are caused by a number of causes. Up to 75% of teachers who have tried particular forms of active learning give up on the practice completely because they don't think the work needed to implement it is worthwhile. Limited awareness and understanding of the benefits of active learning methods also contribute to the low adoption rates (Froyd et al., 2013; Geoffrey et al., 2015). A large-scale study in biology courses found that typical instructors lacked the knowledge to effectively implement active-learning teaching methods, suggesting potential challenges in adopting new instructional approaches. Factors such as class size, content coverage pressure, and instructors' personal views and experiences with teaching can influence instructional decisions and the adoption of active learning (Stains & Vickrey, 2017; Tang & Liao, 2021).

The term "active learning" has become a generic term for a variety of teaching strategies, most of which involve more physical interaction or engagement, deeper cognitive processing, content elaboration or explanation, task organization, questioning, metacognitive awareness, and interaction with others (Al Mamun et al., 2022; Torres-Gastelú & Kiss, 2016). This variability makes it difficult to identify the precise elements that affect performance differences in active learning methods. Since active learning differs from passive learning in many ways, it is still difficult to identify whether forms of active learning are beneficial or detrimental when used by teachers.

This issue arises due to instructors' lack of knowledge regarding active learning, making this study crucial to conduct. Active learning encompasses a wide range of types and variations, thus necessitating research that provides insight into the various active learning methods previously utilized. Such research serves as valuable information for instructors to consider when contemplating the adoption of active learning strategies. It is crucial to examine whether active learning aligns with the fundamental concepts and theories. Thus, there is a need for systematic research related to the type of active learning offered from several existing studies to see the variations and the possible developments, so that they can be used as references for other researchers, teachers, students, pre-service teachers, and other stakeholders. This study was conducted to review the type of active learning implementation in science education.

2. METHODS

This type of study is library research with several procedures (Celik, 2018). The procedure entails identifying the research topic, establishing inclusion criteria for content analysis, conducting analysis, coding, and ensuring validity, and finally, presenting and synthesizing the findings based on relevant literature. The primary focus of this study is to investigate the application of active learning in science education. International journals sourced from the Royal Society of Chemistry, International Journal of Instruction, Universal Journal of Educational Research, Jurnal Pendidikan IPA Indonesia, Journal of Baltic Science Education, Journal of Chemical Education, and International Journal of STEM Education were utilized for this purpose. The search was conducted using the keywords "Active Learning." The search process involved setting a specific data range from 2012 to 2022.

The journals used in this study are based on inclusion criteria, 1) Effectiveness of active learning, 2) Student perceptions of active learning 3) Instructor experience using active learning 4) Instructor strategies using active learning 5) Leaning assistants supporting active learning. For Example previous study discuss the effectiveness of active learning in organic chemistry faculty development workshops (Houseknecht et al., 2020), and other study discusses the student-centered active learning approaches to teaching quantum chemistry and spectroscopy (Partanen, 2018). On the other hand, the exception articles used are those that do not discuss active learning in science subjects. For Example, study that discuss gamification and active learning in higher education at the faculty of business and economics (Fuad et al., 2020). Following an initial search, titles and abstracts of articles were screened for relevance, and full-text articles meeting the inclusion criteria were thoroughly reviewed. Data were extracted from selected studies, including course, type of active learning, aims, methods, samples, and data collection tools. This study has prioritized the type of active learning that is generally used in science education.

To ensure that the selected articles meet the inclusion criteria, two judges were involved in assessing the relevance of each article. There are 25 journals that researchers analysed the contents of and found 20 journals that fit the criteria based on the agreement between the two judges. The authors individually continue coding all articles that fit the criteria. The coding results were subsequently validated by a chemistry educator to ensure that the assigned codes accurately represented the priority categories described in each article.

3. RESULTS AND DISCUSSION

Results

The course theme consisted of five different codes. The first code, “Interdisciplinary chemistry,” has the highest number. Another code is “science, technology, engineering, and math (STEM),” which consists of six articles. The third code is “Not applicable,” and consists of three articles. The fourth code is “Biology,” consists of two articles and the last code is “Mathematics” consists of one article used in this course. Frequencies of the course theme via the codes can be seen in Table 1.

Table 1. Frequencies of Course Theme in The Active Learning Studies

Theme	Codes		f
Course Theme	Interdiciplinary chemistry	Biochemistry	3
		Organic chemistry	1
		Physical chemistry	1
		Alkaline earth metal concepts	1
		General chemistry	1

Theme	Codes		f
		Quantum chemistry and spectroscopy	1
		Total	8
	STEM		6
	Not applicable		3
	Biology		2
	Mathematics		1
	Total		20

The active learning themes consisted of seven different codes. The first code, "Not applicable," had the highest number. The second code, "Others," was presented in four articles. The remaining codes, including hybrid learning, group work, online-based learning, hands-on learning, and inquiry, were equally represented, with three articles each. Frequencies of the type of active learning via the codes are displayed in Table 2.

Table 2. Frequencies Type of Active Learning in the Active Learning Studies

Theme	Codes	f
Type of Active Learning	Not applicable	6
	Others	4
	Hybrid learning	3
	Group work	3
	Online based learning	3
	Hands-on Learning	3
	Inquiry	3
Total		20

The aim theme consisted of three different codes, those are fourteen articles aim to investigate the effects of active learning on a related variable, four articles aim to review research about active learning, and two articles aim to generate an instrument measuring active learning. Frequencies of the aimed theme via the codes are presented in Table 3.

Table 3. Frequencies of Aim Theme in the Active Learning Studies

Theme	Codes	f
Aim	Investigate the effects of active learning on related variable	14
	Review research about active learning active learning in class, students' outcomes metacognitive regulation)	4
	Generate an instrument measuring active-learning	2
Total		20

The method theme consisted of eight different codes. Based on Table 4, it can be seen at the end of the last ten years, the type of dominant active learning study carried out in a quantitative method.

Table 4. Frequencies of Method Theme in the Active Learning Studies

Theme	Codes		f
Method	Quantitative	Experimental	7
		Survey	3
		Quasi-experimental	2

Theme	Codes		f
		Case study	1
	Qualitative	Literature review	4
		Phenomenology	1
		Content analysis	1
	Mixed-method	Not specified	1
	Total		20

Frequencies of the method theme via the codes are displayed in Table 4. In this study, there were thirteen quantitative studies analyzed. They were seven experimental, two quasi-experimental, three surveys, and one case study. Besides them, there were six qualitative designs. There was one phenomenology, four literature reviews, and one content analysis. In this study, there is one journal using mixed methods with not specified detailed methodology. The sample theme consisted of four different codes. Frequencies of the sample theme via the codes are presented in Table 5**.**

Table 5. Frequencies of Sample Theme in The Active Learning Studies

Theme	Codes	f
Sample	Undergraduate students	8
	Student	4
	Article	4
	Instructors	3
Total		20

As presented in Table 5, the most frequent sample theme involved undergraduate students, with eight articles utilizing this subject. Next, four articles used student subjects. "Students" refer to elementary school students, middle school students, and high school students. The results of this study also indicate that there were four articles using other articles as the subject of study. Lastly, there were three articles using instructor subjects.

The data collection tool theme consisted of eight different codes. Frequencies of the data collection tool theme via the codes are presented in Table 6.

Table 6. Frequencies of Data Collection Tool Theme in the Active Learning Studies

Theme	Codes	f
Data	Survey and descriptive	7
Collection	Questionnaire	5
Tool	Multiple-choice question	5
	Open-ended question	4
	Literature	2
	Scale	2
	Not applicable	2
	Computer system	1
	Total	28

Base on Table 6, they are seven survey and descriptive, five questionnaires, five multiple-choice questions, four open-ended questions, two for literature, scale, and not applicable respectively. In addition, only one article uses computer systems as a data collection tool.

Discussion

This section addresses the research issues that guided the study and presents the analysis's findings. First, in response to the first research question in the context of active learning studies, it was found that interdisciplinary chemistry is the course that is studied the most frequently. Eight studies out of 20 examined them. Biochemistry was the most interdisciplinary chemistry concept examined. Previous study had reasons why they took the interdisciplinary chemistry concept because it allows students to think at a systems level and consider the broader impacts of their work, moving beyond the traditional focus on environmental and human health (Dewi et al., 2019). Interdisciplinary chemistry holds significance as it enables the integration of knowledge from various scientific disciplines to tackle complex problems in chemistry, thereby enhancing the educational process and elevating the quality of teaching chemistry (Fioletov et al., 2022; Goeltz & Cuevas, 2021).

The type of active learning conducted revealed that the most utilized type was ‘not applicable. From 20 studies, 6 studies discussed them. These journals were coded as not applicable since they did not have any type of active learning that was used in science classrooms. The next type of active learning was coded under ‘others’ since they did not have any specific active learning that was used in a science classroom (Cho et al., 2021; Suharko & Kusumadewi, 2019). There were 4 journals coded ‘others’ using flipped classroom, group work, group discussions, alternative assessments, the combination of active learning strategies and metacognitive regulation, goal-oriented, intentional learning, and concept-point-recovery (CPR).

This result is consistent with a study, which found that discussion, group work, and metacognition were the three active learning strategies most commonly mentioned (Driessen et al., 2020). Previous research has also indicated that teaching strategies such as design projects, small group instruction, and problem-based learning have been proposed as the educational remedy for the prevalent reliance on lecturing in higher education, which is often depicted as the embodiment of passive learning instruction (Anakin & McDowell, 2021; Deslauriers et al., 2019). This result is consistent with a study by Driessen et al (2020), which found that discussion, group work, and metacognition were the three active learning strategies most commonly mentioned (Driessen et al., 2020). According to earlier research, lecturing—which is often depicted as the embodiment of passive learning instruction—is not the only instructional strategy that has been proposed as a substitute for problem-based learning, small group instruction, and design projects in higher education.

The lack of a clear definition of active learning renders instructors without a clear perspective on whether active learning is activity-driven or emphasizes engagement. The definition of active learning has not been entirely useful for the development of instruction and research focused on active learning (Doolittle et al., 2023; Wahyuni et al., 2022). When examining active learning definitions, most articles do not provide any definition of active learning at all. Due to the ambiguous nature of the definition, the types of active learning identified in this study are quite broad. In many cases, instructors may employ active learning strategies differently from how they were initially intended by developers and even small decisions regarding the implementation of a teaching strategy can have substantial effects on student learning (Dancy et al., 2016; Knight et al., 2013). Previous study have demonstrated that the outcomes achieved by instructors using active learning can vary significantly (Eddy & Hogan, 2014). An instructor's knowledge plays a crucial role in how they plan and execute active learning instruction, which ultimately impacts student learning (Blömeke et al., 2015; Stains & Vickrey, 2017).

The most frequency aims theme in studies analyzed is ‘Investigate the effects of active learning on a related variable.’ This demonstrates the wide range of research conducted on how individuals actively absorb science concepts. The growing corpus of research demonstrating the efficacy of student-centered and active learning approaches is making them more and more popular in the scientific (Freeman et al., 2014; Lombardi & Shipley, 2021). A variety of techniques have been used over time to investigate active learning in science. For instance, suggests a student-centered method for quantum chemistry and spectroscopy instruction at the bachelor's degree level (Partanen, 2018). This method integrates the ideas of active learning in addition to standard lecture-based learning. This aims theme is conducted deeply with undergraduate students, with 7 journals utilizing this subject. Therefore, other study noted that low adoption rates of active learning continue to be an issue and that traditional teaching approaches like lecturing still predominate in undergraduate STEM courses (Stains et al., 2018).

The most frequent method theme in these studies used quantitative methods, maybe because they are better suited to investigate active learning, particularly in science classes. Furthermore, their research, which tries to examine the impacts of active learning on associated variables, may be the cause of the disparate numerical connections between quantitative and qualitative designs. For instance, the most commonly utilized design was experimental, with seven studies. Due to the fact that there were four literature reviews, one phenomenology, and one content analysis that required in-depth study, it is conceivable that few active learning studies employed qualitative approaches. Mixed-method studies had the fewest active learning research, suggesting that they might not be the best way to investigate this kind of learning.

The most frequent sample theme in this study involved undergraduate students consisting of undergraduate students and pre-service teachers. The next code is student and articles were represented equally with four articles. The lowest number of sample themes is instructors presented three articles including instructors and high school teachers. The second sample was followed by the students including high school students and primary students. This is because of the relationship between university students who will later be involved in the science teaching process in high school (Wardah & Wiyarsi, 2020). The fact that most chemistry instructors have limited exposure to active learning, both as students and instructors. They have dedicated considerable time and effort to becoming skilled at delivering content through traditional lecture-based methods. While resistance to change, especially among senior colleagues, may be diminishing, it still poses a significant obstacle for many chemistry instructors (Damşa et al., 2021; Owens et al., 2020).

The most common theme for data collection tools in this study was surveys and descriptions, as seen in many studies aiming to investigate the effects of active learning on related variables. Based on the coding results obtained, many research studies proceed with the data analysis process through description. Surveys and descriptions are also frequently utilized in qualitative study, as they can be the appropriate tools for collecting data in active learning studies. Through qualitative processes, participants can articulate scientific concepts via surveys and interviews. Furthermore, active learning has been examined through multiple-choice questions and questionnaires. Other commonly used data collection tools in active learning study include open-ended questions, literature reviews, scales, and computer systems. Some studies did not have a specific data collection tool. Each of these data collection tools has its strengths and limitations. Consequently, many active learning studies incorporate multiple data collection tools within a single study to enrich the collected data.

4. CONCLUSION

According to the review's findings and research questions, the most frequently examined course is interdisciplinary chemistry. The types of active learning themes consisted of seven different codes: not applicable, others, hybrid learning, group work, online-based learning, hands-on learning, and inquiry. This study found that articles aim to investigate the effects of active learning on related variables. The most frequent method theme in these studies used quantitative methods. These studies were also enriched by the participation of undergraduate student samples, with data collected through surveys and descriptions. These findings may serve as considerations for instructors to adopt suitable active learning strategies, impacting students' achievements in science education.

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