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Systematic Literature Review: A System Thinking in Chemistry Learning

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Abstract: This study aims to identify systems thinking in chemistry learning. The research method used is a systematic literature review (SLR) by analyzing relevant research results from the Google Scholar and ERIC databases of 33 articles based on their suitability with the research theme within the last seven years (2015-2022). Through the SLR method, articles are reviewed systematically by following the steps that have been determined. The research findings show that system thinking students mostly occur in general chemistry. The application of the Dual Situated Learning Model (DSLM) as well as implementing the Elicit, Confront, Identify, Resolve, Reinforce (ECIRR) mode.

Keywords: Chemistry learning; Systematic literature review; Systems thinking

Introduction

A changing world that is becoming more complex has made sociotechnical systems recognized as "the environment we live in" (Strijbos & Wichmann, 2018; Kornfeld & Stokoe, 2019). System thinking is considered to be very useful in modern life, where system thinking is about finding patterns to strengthen or change these patterns to achieve personal fulfillment. This can actually help simplify our lives because we can see the interconnection between what at first looks like different parts. The learning process also continues to develop, and learning at school is also becoming more complex. Chemistry is a compulsory subject in senior high school. For high school students, especially students who are new to this subject, chemistry is a difficult lesson so students feel they are not able to learn it. Students' difficulties in learning chemistry can stem from difficulties in understanding terms, difficulties with numbers, d and difficulties in dealing with chemical concepts (Arifin, 1995; Anugrah, 2019; Antari et al., 2020). A deep understanding of chemical concepts (conceptual understanding) is likely to be achieved if students can relate their relevant chemical knowledge to make comparisons, translations, and judgments. Conceptual understanding is also demonstrated by presence recognition and the creation of relationships between chemical concepts (Miller et al., 2019; Francisco et al., 2002; Nesbit & Adesope, 2006; Aubrecht et al., 2019; Mammino, 2019; Chiu et al., 2019; Johnson et al., 2020).

System thinking is able to make students more organized in learning a concept, students will relate one concept to another and this is able to make students far more able to understand concepts in more depth. Richardson (2008) defines systems thinking as an intellectual attempt to uncover intrinsic causes of system behavior. Shows that what we mean by the word "understanding" is knowledge of endogenous forces operating within a system. With an understanding by using system thinking, learning can be more in-depth with students being able to connect the

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interrelationships between one concept and another. This learning must be applied in chemistry because some chemical material is difficult for students to understand if the teacher only explains it through a medium. The presence of system thinking which is considered a novelty in the learning process is able to make students more interested in learning chemistry.

The linkage between one variable and another variable can be explained by system thinking. The concept of systems thinking offers a different model of thinking, a new way of approaching and understanding the world. Currently, chemistry education researchers emphasize the need to reorient chemistry education through systems thinking, which has been considered an important component of chemistry advancement (Matlin et al., 2016; Lasker, 2019; Holme, 2020; Flynn et al., 2019; Constable et al., 2019; Pazicni & Flynn, 2019; Eaton et al., 2019; Hayes et al., 2020; Jackson & Hurst, 2021; York & Orgill, 2020). System thinking is considered capable of making students understand chemistry concepts much more deeply because with this they are able to connect the interrelationships of one sub-material with other sub-materials. Therefore, the system thinking approach is capable of solving student problems. The problems that are present at this time require the skills of students to find solutions to these problems. One means of practicing problem-solving is the activities carried out at school by applying problem-solving strategies. The use of problem-solving strategies can make students obtain some information, knowledge, experience, and new abilities in the learning process.

Method

This study uses the Systematic Literature Review method by identifying and systematically reviewing journals. The research focus is on the analysis or identification of students' system thinking in chemistry learning. The data collected comes from the Google Scholar and ERIC databases in the last eight years, from 2015 to 2022. As for the articles reviewed, 33 articles were obtained using the keyword "System thinking approach in chemistry", so several articles with titles around those keywords.

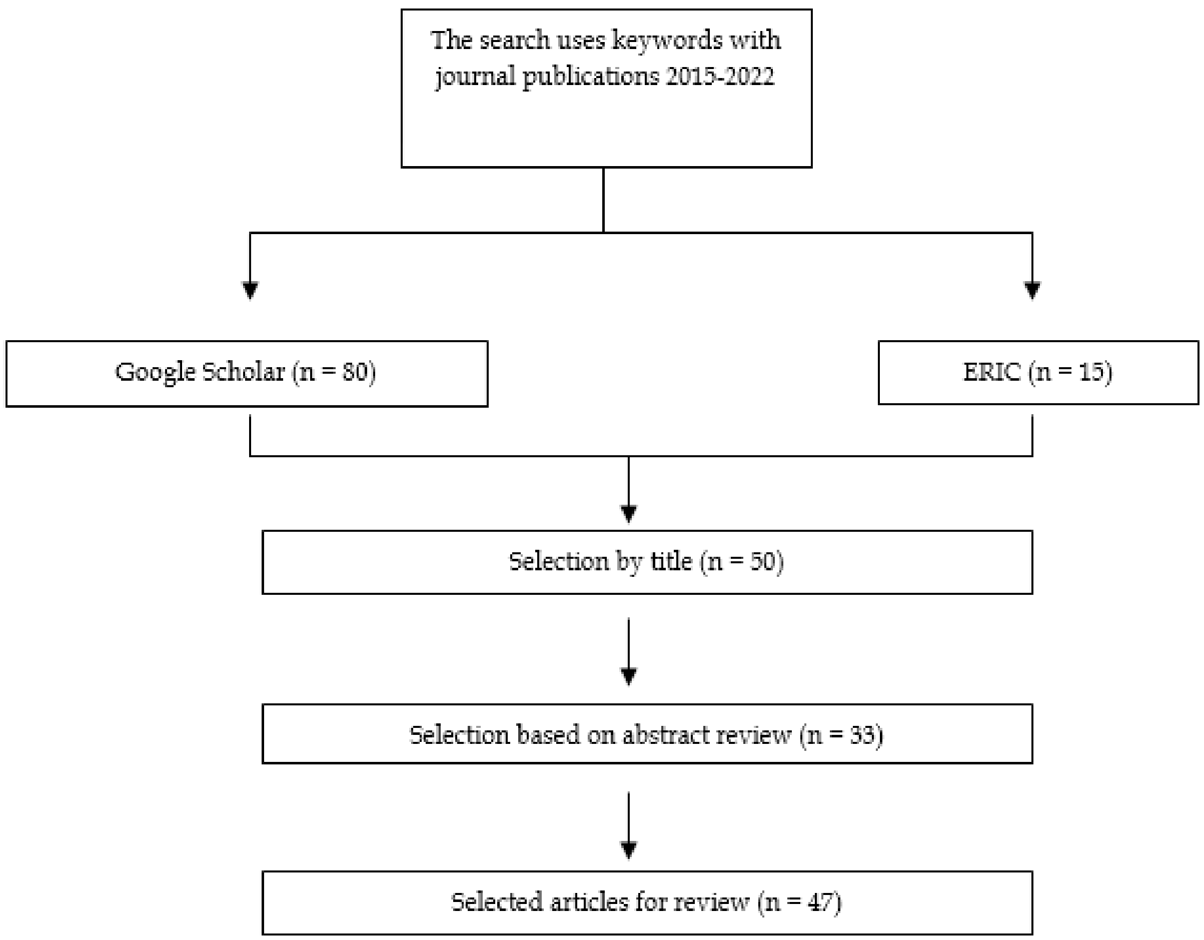

Figure 1. Article selection process flowchart

The articles used in answering research questions are national and international articles indexed by Scopus and Sinta. Therefore, articles that did not meet these criteria were not selected. The steps in a systematic literature review according to Siswanto (2010) consist of: formulating research questions; conducting a systematic review literature search; conducting screening and selecting suitable research articles; conducting analysis and synthesis qualitative findings; and prepare a final report. The research questions formulated were What were the aims of system thinking in chemistry?; What methods did these studies use?; Who were the samples involved in these studies?; What data collection tools did these studies use?; What data analysis techniques did these studies apply?; What chemistry concepts did these studies focus on?; Which recommendations did these studies offer? After the research questions were formulated, a literature search process was carried out through the Google Scholar and ERIC databases, 115 articles were obtained and the selection or filtering was carried out according to the selection criteria so that 33 articles were indexed by Scopus and Sinta. The process of selecting or screening articles for review using the Prisma standard can be seen in Figure 1.

Result and Discussion

Results

The literature that has been obtained is then coded into several predetermined criteria. Can be seen in the following explanation.

Result of Chemistry Concept

The frequency of conceptual chemistry can be seen in Table 1. The table consists of 8 chemistry concepts, which include 9 for general chemistry, 2 for inorganic chemistry, 7 for biochemistry, 2 for laboratory, 3 for organic chemistry, 3 for physical chemistry, 1 for core chemistry, and 6 for analytical chemistry where this totals 33.

Table 1. Frequencies of chemistry concept

Paper Code	Course Code	f
1, 3, 11, 15, 25	General Chemistry	9
7, 15	Inorganic Chemistry	2
3, 5, 8, 13, 14, 18, 20	Biochemistry	7
22	Laboratory	2
12. 34	Organic chemistry	3
2, 16, 33	Physical chemistry	3
23	Core chemistry	1
9, 10, 17, 19, 21, 31	Analytical chemistry	5
Total		32

Result of Aim Theme

The frequency of the goals that have been coded can be seen in Table 2. In Table 2 there are 11 different objectives.

Table 2. Aim theme

Theme	Codes	f
Aim	To investigate the effect of the implementation of System Thinking.	6
	Explore system thinking of chemistry concept.	5
	To give enough basic system info about systems thinking approach.	3
	Explore the relationship between students' understanding in chemistry and the development of basic systems thinking skills.	8
	Explore the relationship between the two constructs of interest based on students' performance on the applied assessment framework.	1
	Application of systems thinking for the practice of chemistry education.	2
	Develop the assessment a system thinking perspective.	1
	The assessment of student understanding within a system thinking perspective.	3
	Contextual problem-solving in representations through the lens of systems thinking.	1
	Develop system thinking for future skills.	3
Amount		33

Result of Method Theme

Frequencies of the method theme via the codes are displayed in Table 3. The method used is qualitative, namely 7 with case studies, 1 content analysis, 1 explorative quantitative study, 11 quantitative descriptive studies, 1 mixed method, 3 qualitative, 2 surveys whereas.

Table 3. Theme method

Theme	Code		f
Method	Qualitative	Case study	7
		Content analysis	1
		Explorative studies	1
	Quantitative	Quantitative descriptive	11
		Mix method	1
		Qualitative	3
		Surveys	2
Amount			26

Result of Chemistry Concept Theme

The frequency of the chemistry concept theme via the codes can be seen in Table 4.

Table 4. Sample chemistry concept theme

Theme	Codes		f
Sample	Student	University	16
		High school	13
		Middle school	1
	Teacher	Instructor	1
		Preserves	1
Total			32

Result of Data Collection Tool Theme

The frequency of the chemistry concept theme via the codes can be seen in Table 5.

Table 5. Data collection tool themes

Theme	Codes	f
Data collation tool	Questionnaire	3
	Multiple-choice question	1
	Written text	10
	Worksheets	8
	Interviews	3
	Observations	5
Amount		30

Result of Data Analysis Theme

Table 6. Data analysis theme

Theme	Code		f
Data Analysis	Qualitative	Coding	10
		Content analysis	4
	Quantitative	T-test	1
		ANOVA	9
		ANACOVA	3
		Man-Whittney	3
Amount			30

Table 7. Frequencies of chemistry concept theme

	Code	f
Inorganic Chemistry	Chemical Bonding	1
	Atomic structure	1
Biochemistry	Green Chemistry	3
	Climate change	4
Organic chemistry	Carboxylic acid	2
	Carbonyl compound	2
Physical chemistry	Homonuclear versus heteronuclear bonds	1
	Gas laws	
	Energetic and entropic factors	1
	Thermodynamics	2
Core chemistry	Radioactive	1
Analytical chemistry	Acid base	5
General chemistry		1
Total		24

The data analysis used is. In addition, other qualitative data analyzes used were 4 for content analysis, 3 for constant-comparative techniques, 3 for inductive analysis, and 2 for phenomenographic analysis. Furthermore, there were quantitative data analysis techniques which include t-test, descriptive statistics, Wilcoxon test, ANOVA, and inferential statistics have 6, 4, 3, 2, and 2 respectively. And then, only one article which used ANCOVA, Fisher's exact test, Kruskal Wallis Test, LCA (Latent Class Analysis), MANOVA, Pearson correlation, Regression, and Two-tailed analysis.

Discussions

Table l contains the chemical materials used in the reviewed literature. It can be seen that the frequency of each material is different. In the first material, namely general chemistry, there are 9 literature with paper codes 1, 3, 11, 15, and 25. This material is the most widely used because there are more explains the chemical material as a whole but not in depth. The next material is inorganic chemistry with a number of frequencies, namely 2 with data codes 7 and 15. and paper codes 12 and 34. Furthermore, organic chemistry with frequency 3 and paper codes 3, physical chemistry 3 with paper codes 2, 16 and 33. Most used in these studies is general chemistry because there are so many chemical concepts that are interconnected and require a deep understanding so the use of system thinking is very helpful.

The results of the subsequent analysis are the most analyzed goals, the most discussed goals are "Explore the relationship between student's understanding of chemistry and the development of basic systems thinking skills. This indicates that students' understanding will greatly affect their system thinking ability, with system thinking they will be able to relate one concept to another. According to Theodore, system thinking has several steps, including in the first step, some individual and conceptually isolated concepts and/or links are identified within the defined conceptual system. In the second step, two or more components are recognized as connected with a specific and predetermined (interrelated) relationship, formulating a conceptual subsystem that is a part of the whole system. In the third step, the identification of two or more subsystems is accomplished, that is, the identified components are related to two or more specific relationships. In a final step, all the interconnected parts/subsystems are recognized, namely, the whole system of interest is identified. Furthermore, the most widely used goal is " investigate the effect of the implementation of System Thinking". The positive impact of the implementation of system thinking is that it is easier for students to understand a concept without having to explain it repeatedly.

System thinking studies frequently used quantitative descriptive this is because in measuring students' system thinking abilities it must be seen from the results of their learning, which provide many learning processes that train students in connecting one concept to another. In Table 3 the second most frequent frequency is qualitative with pocket study, this is because from the case study students are able to solve it themselves and are able to see how system thinking is used in the learning process. The next fact is that most mental model studies involve students, both high school and university students (see Table 4). This is caused by the relationship between university students who will later be involved in the chemistry teaching process in high school. More studies are involved in chemistry educational program students as samples because they are pre-service teachers who will be directly involved in chemistry learning in the school. From the data from the coding results, University students were the most selected sample with a frequency of 16 and high school students with a frequency of 13. University students were the most widely selected sample because this system thinking is most suitable to be applied at that level where they are able to understand things more complex in chemistry. At the university education level, students have studied chemistry in depth so that it is not too complicated to show system thinking.

Then the data from the coding results with a frequency of 13 are high school students. As presented in Table 5, the mental model studies mostly exploited written text because maybe this is the right data collection where students will be given a text that they will answer. For example, in Orgill et al. (2019), where she gave a text containing a chemical concept that was connected to one another, and students were asked to fill in a few blank words, this was considered to be able to make students able to make the connection. Where students can be creative depends on their understanding. Some words are already in place and others are still blank. From these tools, participants can get answers that are illustrated through drawings, diagrams, maps, and others. Furthermore, using a worksheet is not much different from the written text on a worksheet which also contains a number of questions to be answered by students.

Next is the highest frequency of mental model studies using qualitative data analysis (see Table 6), especially coding analysis. This is in accordance with many studies that aim to explore mental models and then classify them through the coding process. Based on the coding results that have been obtained, then a lot of research continues the process of data analysis through the description process. This description process turns out to be able to use qualitative techniques, it can also be done through quantitative, namely through descriptive statistics. However, from 33 data analysis techniques that have been presented, there were only 15 quantitative data analysis techniques that were spread evenly through the t-test, ANOVA, ANCOVA, and Man-Whittney. In qualitative, there is coding and content analysis.

Based on the results of the frequency on the chemical concept of system thinking is acid-base. Acid-base material is material that instills a lot of concepts, this concept is very necessary for subsequent material and is very influential in the future so students' deep understanding is needed, concepts in science and its concepts are abstract, so the way to teach and learn about the atomic theory must be well considered. They have to relate concepts where they have to know about pH calculation and so on. Furthermore, namely on organic chemistry, this material is broad and must be understood in depth as one of the most important topics taught in chemistry at the high school level. In addition, a study by Salame et al. (2019) understanding organic chemistry is particularly important since further learning depends heavily upon it. Such as research conducted by Vladušić et al. (2016) chose the concept of chemical bonding because students were vulnerable to using alternative concepts in representing this concept.

System thinking is an approach that is much needed in today's modern learning, considering that this approach has been highly developed in other countries and is widely applied in the world of science. This approach should be able to be applied to the field of chemistry learning either in high school or at university because it is able to make students think at a high level about the relationship between one concept and another.

Conclusion

The conclusion that can be drawn is that from the review data obtained several facts that the use of system thinking has been highly developed from 33 articles that were suspected with regard to their aims, methods, samples, data collection tools, data analysis tools, chemistry concepts, mental model theories, and recommendations of the studies. The result of this research is that quantitative studies with various designs were adopted more in these studies, the data collection technique that is often used is written text with the most researched samples at the tertiary level.

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Author Contributions
Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, A.K.S.K.; writing—review and editing, visualization, supervision, project administration, funding acquisition, D.N.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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