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Case-Based Learning (CBL) in Chemistry Learning: A Systematic Review

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Abstract: The implementation of Case-Based learning in chemistry learning has grown rapidly in the last ten years. To find trends and issues in the application of case-based learning in chemistry learning, a systematic review is needed. This study aims to analyze the types of CBL and forms of CBL cases used in chemistry learning. The research method used is a systematic review of articles published in the Scopus journal obtained from the Scopus database for the last 10 years (2011-2021). Search articles using titles, abstracts, or keywords that meet logical conditions ("Case-Based Learning") or ("Case Method") and ("Chemistry"). The population of this study was 200 articles published in the Scopus database and the sample used was 93 articles. The findings showed that the CBL learning model has a learning syntax that includes four (4) stages, namely: Case Orientation (determining the object to be tested), Peer Instructions (choosing cases that are relevant to the object being studied), Case Review (building initial theory and reviewing literature), Evaluation (collecting, organizing data, analyzing data and developing conclusions). The CBL model presents complex cases in the form of factual news related to the essence of the problem context in the form of story descriptions and integrates information sources in the context to solve cases. The percentages of the 93 articles analyzed were 32% PBI, 31% PBL, and 30% PJBL. Thus, it can be concluded that CBL learning is implemented in three (3) learning approaches, namely CBL in Inquiry-Based Learning, CBL in Problem Based Learning, and CBL in Project-Based Learning.

Keywords: Case-Based Learning; Chemistry Learning; Chemistry Courses

Introduction

The problem of learning chemistry encountered at various levels of education is that most of the chemical concepts become abstract concepts for students and they cannot even recognize the key concepts and relationships between concepts needed to understand the concept so students do not have an understanding of chemical concepts. Which is basic at the beginning of their study of chemistry. This results in the understanding students obtained tends to be limited to understanding theory without understanding real life, so students are not able to think scientifically about events that occur in real life (Zhao et al., 2020; Jamari et al., 2018; Günter & Azman, 2019). In addition, there are several key issues with how chemistry is traditionally taught: (1) the content of the material is overloaded due to the rapidly expanding body of scientific knowledge; (2) the absence of a clear goal of learning chemistry because the curriculum is taught as an aggregation isolated facts that do not facilitate the establishment of meaningful relationships between facts; (3) lack of transfer of problem-solving skills; (4) lack of relevance to student life; and (5) Inadequate emphasis on skills required to study further chemistry studies. The idea of setting chemistry in certain contexts to increase student involvement in learning has become increasingly popular in the last 5 years (Bortnik et al., 2021; Podschuweit & Sascha, 2018).

In the learning process, this context can be taken as a starting point to ask chemistry-related questions, to apply and deepen knowledge of chemistry, and to develop competencies such as argumentation about chemistry. Context-based problems are usually not simple questions that can be answered by rote learning

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or algorithmic scripting but require different problem-solving skills. Solving problems embedded in authentic contexts often implies special challenges and demands on student abilities (Broman et al., 2018; Zhao et al., 2020; Kang et al., 2019; Günter et al., 2019).

Thus, one alternative solution is to apply Case Based Learning in chemistry learning. Case-Based Learning (CBL) is an active learning strategy, focusing on the student as the centre of the learning environment to encourage community-based, student-centred and situation-specific exploration. Students focus on cases and engage in independent learning, scientific inquiry and collaboration with peers, develop critical thinking and problem-solving skills, integrate theory into practice. The urgency of the application of CBL in learning is to provide a practical model for students in connecting content learning with practice and help them improve their ability to learn to collaborate, think critically, and solve problems. Case-based learning has been delivered in various curricula, and feedback received from students showed that CBL significantly improves student understanding (Bi etal., 2019; Jamari et al., 2018; Günter & Azman, 2019; Suwono et al., 2017).

Although there are many studies that reveal the application of case-based learning, including CBL, can effectively increase students' motivation to learn chemistry and chemical attitudes towards chemistry in general chemistry courses (Çam & Geban, 2017). CBL is effective in increasing student academic achievement and positive student perceptions in the analytical chemistry laboratory practicum course on the topic "Acid-Base Titration" (Günter, et al. 2019). CBL effectively makes it easy for students to conduct experiments with online Biochemistry laboratory equipment (Thibaut & Schroeder, 2020). CBL can effectively introduce green chemistry principles to students through the use of case-based learning modules in environmental chemistry courses (Ballard & Mooring, 2021). CBL can effectively improve academic achievement and positive perceptions of students in environmental chemistry courses on the topic of BOD (Günter & Alpat, 2017). But in reality, there are still problems faced by lecturers and students during the implementation of CBL, namely: lecturers have difficulty designing cases that can be used as research instruments in case-based learning (Çam & Geban, 2017); lecturers difficulty in systematically developing learning objectives clearly according to the workload and time limit in case-based learning (Bi et al., 2019 & Jamari et al., 2018); students find it difficult to build answers from the cases given because they do not understand the case (Günter et al., 2019); students have difficulty in articulating and summarizing conclusions clearly and concisely according to the given case (Suwono et al., 2017); students find it difficult to get proper guidance on the implementation of the necessary cases (Thibaut & Schroeder, 2020; Ballard & Mooring, 2021). From these problems, the impact for teachers and researchers in implementing and developing CBL is that they can provide an overview of the initial conditions of learning in the application of CBL and learning conditions after CBL is applied. This is important because it can change the mindset of teachers about the application of CBL to be better prepared in implementing effective CBL in chemistry learning and there is a need for training for teachers and researchers in implementing CBL, preparing teaching materials, media, and CBL-based teaching materials.

Characteristics of case-based learning include: 1) decision-oriented is a case describing a managerial situation in which a decision must be made immediately, but does not reveal the result; 2) active participation of students in analyzing the situation; 3) development of written case material discussions to bring up various views and analyzes developed by students; 4) substance is a case consisting of the main part that discusses issues and information; 5) questions are cases usually don't ask questions because understanding what should be asked is an important part of case analysis (Kulak & Newton, 2014; Sen, 2017; Dewi & Hamid, 2015; Dewi & Handayani, 2015). The application of case-based learning is used to 1) demonstrate theory in practice and provide practical examples; 2) facilitate problem-solving and decision making by providing context for applying models, tools and techniques; 3) encourage critical analysis and discussion; 4) develop critical and creative thinking skills; 5) improve work, provide opportunities to practice realistic skills. The implementation of case-based learning requires preparation and clear instructions about student responsibilities to discuss cases in class so that students can develop solutions to the questions that have been prepared. Cases that have prepared are used by lecturers to monitor students' ability to apply knowledge and principles of real experience, useful for identifying some of the main concepts (Jamari et al., 2018; Günter & Azman, 2019; Suwono et al., 2017; Garcia-Ponce et al., 2021; Kulak & Newton, 2014; Nair et al., 2013).

Based on the problems above, that there is nothing systematic review of the types of CBL and the appropriate and effective forms of CBL cases to be applied, especially in chemistry learning. This literature study is important to do because it can provide a systematic review of the types of CBL and forms of effective CBL cases to be applied as a promising learning model to support the implementation of case-based learning in chemistry learning. For example, the distribution of case-based learning in chemistry courses, specific chemistry courses that may be taught with case-based learning, and the types of CBL that have been used in chemistry learning. The focus of this review study is to analyze the comparison of the learning syntax of the types of CBL that have been implemented and to analyze the form of cases used in CBL learning. The potential contribution that can be made from this review study is that it can provide recommendations regarding the type of effective CBL and the right form of CBL cases to be implemented in chemistry learning and following the characteristics of specific chemistry courses. The problem formulation of this research are a) How is the comparison of the syntax of the CBL types?; b) What is the Case Forms in CBL Learning?

Method

Data Source

This review study aims to analyze the types of CBL and forms of CBL cases used in chemistry learning through the process of investigating articles published in the Scopus journal obtained from the Scopus database for the last 10 years starting from 2011 to 2021 by looking for publications with the title, abstract or keywords meet logical conditions (“Case-Based Learning”) or (“Case Method”) and (“Chemistry”). A total of 200 articles published in the Scopus database correspond to this study consisting of 195 Scopus journal articles from Q4-Q1 with impact factors (IF) ranging from 0.040-3.092 and 5 non-articles (proceedings). The following is a flow chart of the stages of the research that has been carried out.

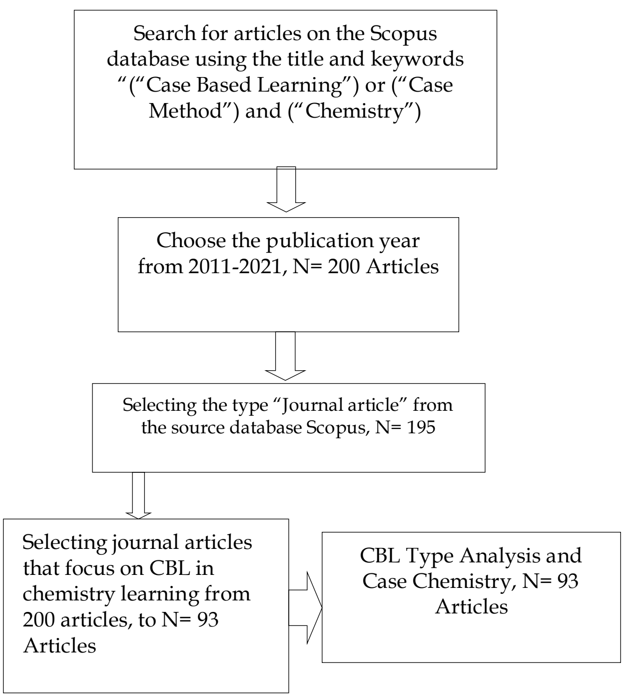

Figure 1. Article Search Stages in the Scopus Database

Data Distribution

The overview of finding articles in the Scopus database using the "Publish of Perish" application. Where, there are 200 articles on CBL learning in general published in 2011-2021 consisting of 195 journal articles and 5 non-articles (proceedings).

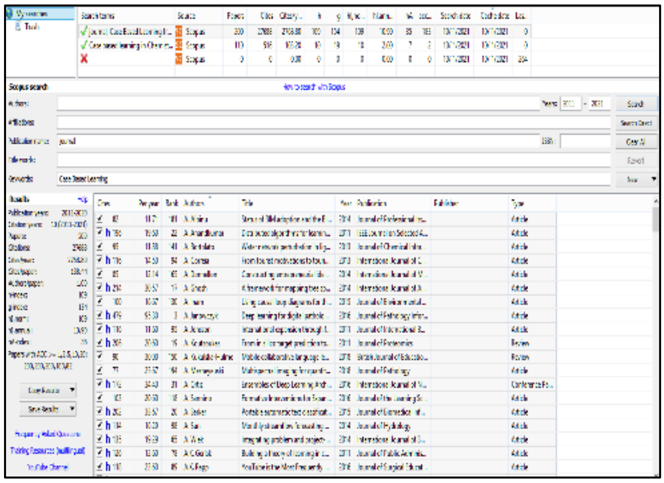

Figure 2. Scopus Database Search

Phase 1

Furthermore, a search was carried out by focusing on the title of the article about "Case-Based Learning" or "Case Method" and the keywords "Case-Based Learning" and "Chemistry" obtained as many as 93 articles researching about it. The following is an overview of the article search results through the Scopus database.

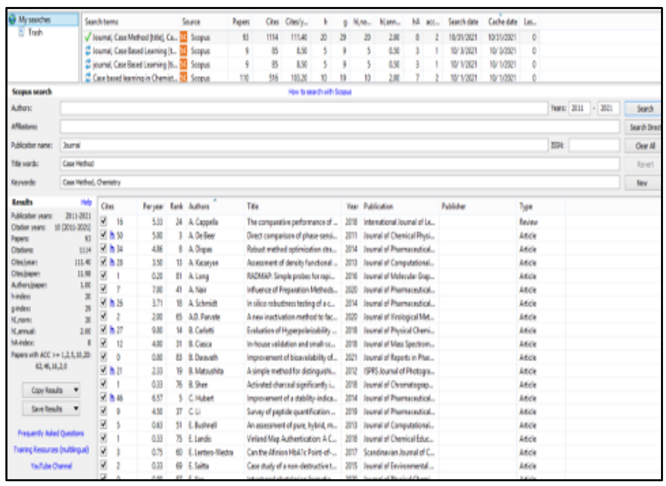

Figure 3. Scopus Database Search

Phase 2

Based on the analysis of the search results, Figure 2 illustrates that there are 93 articles on the application of CBL in chemistry learning from 2011-2021. Articles published in 2011 were 6 articles, in 2012 as many as 4 articles, in 2013 as many as 3 articles, in 2014 as many as 11 articles, in 2015 as many as 5 articles, in 2016 as many as 10 articles, in 2017 as many as 11 articles, in 2018 as many as 15 articles, in 2019 as many as 8 articles, in 2020 as many as 15 articles, in 2021 as many as 5 articles. The following is a graph of the percentage of articles published using case-based learning in chemistry learning from 2011-2021.

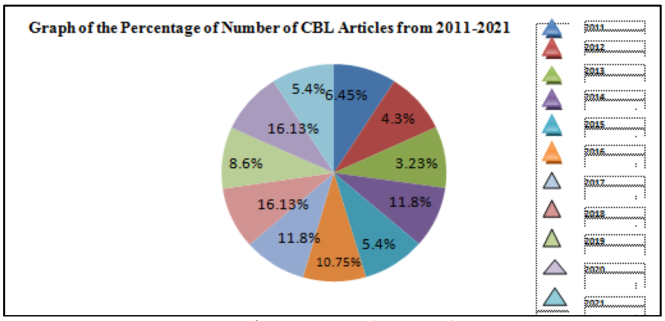

Figure4. Percentage of CBL Articles in Chemistry Learning From 2011-2021

Coding Scheme

In this review study, the categories analyzed related to the types of case-based learning in chemistry learning are classified into 13 namely case study, case, learning, inquiry, simulation, experiment, project, problem, course, game, team, instruction and development. The following classification of case-based learning in chemistry learning is presented in Figure 5.

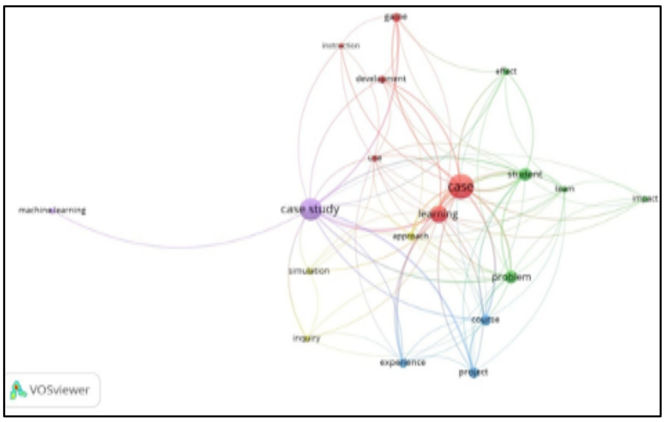

Figure 5. Types of Case-Based Learning in Chemistry Learning

This review study limits the types of CBL to only 8 categories consisting of: inquiry, simulation, experiment, project, problem, game, team, and instruction with consideration of the relationship between the CBL model and 8 categories of CBL types. The direction of the study based on Figure 5 regarding the trends and issues of CBL implementation in the last 10 years shows that there is an interrelated relationship between the types of CBL and the CBL model. This can lead to a comparison of the learning syntax of the types of CBL to be studied more deeply to provide convenience for teachers and researchers in determining the type of CBL and the effective case form to be applied to chemistry learning.

Resultand Discussion

Syntax Comparison of CBL Types

The trend of CBL types in applied chemistry learning from 2011-2021 is illustrated in Figure 3. The highest proportion is in the "case" and "case study". **"Case"**associated with*"Problem"*,*"Project"*,*"Experiment"*, *"Team"*, *"Simulation"*, *"Instruction"*, and *"Game"*. **"Case study" is** associated with *"Inquiry"*, *"Project"*, *"Experiment"*, *"Team"*, *"Simulation"*, *"Instruction"* and *"Game"*. This means that the types of CBL are directly related to problem-based learning, project-based learning, experimental-based learning, inquiry-based learning, team/collaboration-based learning, simulation-based learning, instruction-based learning and game-based learning.

This is evidenced from 93 articles are CBL types consisting of: 30 articles included Experimental-Based Inquiry Learning, 29 articles included Problem-Based Learning, 28 articles included Project-Based Learning, 4 articles included Instruction-Based Simulation Learning and the remaining 2 articles included Game-Based Collaborative Learning. In this case, CBL case types are interpreted as being at one extreme of the case study scenario spectrum with very high levels of self-learning, no or little didactic lectures, high levels of case complexity, and a collaborative, person-led learning environment trained. The case study variants discussed here are lecture-based, directed, experimental, simulation, inquiry, project, game and PBL—differing primarily in the degree to which students are independent and the level of group interaction. The following characteristics of each type of CBL based on syntax and case implementation in chemistry courses are described in Table 3.

Based on Table 3, it can analyze the strength and effectiveness of the implementation of the learning model from the types of CBL, including:

a. Instruction-Based Simulation Learning

Instruction-based simulation learning is a learning model that involves simulation media in the learning process with the aim that students' understanding of concepts increases, especially about observed natural phenomena. The strength of instruction-based simulation learning is that it can arouse emotions, make it easier for students to understand concepts, can stimulate higher-order thinking, and be able to facilitate the achievement of goals to understand and remember information or messages contained in equations, pictures, and graphics (Omoniyi, 2021; Temsah & Safa, 2021; Hurd et al., 2021; Keskitalo & Ruokamo, 2021). The effectiveness of the implementation of instruction-based simulation learning can improve thinking skills, communication skills, conceptual understanding, and can foster courage, self-confidence, and can develop creativity (Omoniyi, 2021; Temsah & Safa, 2021; Keskitalo & Ruokamo, 2021; Kaldheim et al., 2021).

Table 3. Characteristics of Types of CBL Cases in Chemistry Learning

Types of CBL	Case implementation in chemistry courses	CBL Type Syntax
Instruction-Based Simulation Learning	Session one: Cases, test results, learning problems, and reasoning are all integrated into the story. Cases are given as examples to complete the lecture. Instructors can ask students to link cases to lectures.	1) Preparation Determine the topic or problem and the goals to be achieved. 2) Implementation The simulation was started by the cast group to encourage students to think that nature was solving the problem being simulated. 3) Closing Giving instructions to students to conduct discussions both about the course of the simulation and the material of the story being simulated and formulating conclusions (Jones et al., 2021).
Experimental-based inquiry learning	Session one: The case scenario is fully explained: all data and references are provided. All learning problems are provided as directed questions. Everyone gets the same information. Each group in completing all the questions outside the classroom. Session two: Group answers are presented and the instructor facilitates general discussion with the whole class to find answers and consensus.	1) Formulating the Problem The formulation of the problem includes what challenges must be sought for answers related to the problems raised. 2) Collecting data Students are asked to find supporting data as a process of proving the hypothesis through the experimental method. 3) Drawing Conclusions & Data Interpretation The conclusion is obtained as a proof step has been implemented and the conclusions that have been obtained are then communicated to students (Chu et al., 2021).
Project based learning	Session one: Cases are given in the form of questions. Small discussions in class or homework done in groups to develop tentative solutions. Session two: Further details on learning cases and problems are given to the group to develop the topic further. Information from both integrated sessions and completed cases.	1) Prepare questions or project assignments Questions must be able to encourage students to do an activity or project. 2) Design or make plans for the project Planning contains supporting activities to be carried out, useful tools, and materials for project completion. 3) Prepare the implementation schedule for project completion Activities at this stage: (a) create a timeline, (b) determine the final target for project completion (deadline); (c) plan new solutions; (d) explain the reasons for choosing a new method. 4) Monitor project activities and progress The teacher acts as a monitor of student activities while completing the project. 5) Test results Testing of results can be done through presentations or project presentations. 6) Evaluating activities or experiences Reflection on the activities and project results that have been carried out (Ruslan et al., 2021).
Game-based collaborative learning	Session one: Each group received only one of the six learning problems. Each group solves their question so that they become "experts" at it. Session two: A new group is formed with one "expert" from the previous group, so each member shares their answer to one question, and the group integrates all the answers into a general solution for the case.	1) Delivering goals and motivating students; 2) Presentation of information in the form of demonstrations or through reading materials; 3) Organizing students into study groups; 4) Guiding group work and study; 5) Assessment of what learned so that each group presents their work; 6) Give awards both as a group and individually (Tammeleht et al., 2019).

Types of CBL	Case implementation in chemistry courses	CBL Type Syntax
Problem-based learning	Session one: Cases are given depending on the learning objectives. Questions are provided for any group. Session two: Case development relies on student initiatives and contributions. Each group develops its own questions. It may be used completely without lectures.	1) Orientation: Student orientation to the problem. 2) Organizing: Organizing students to learn and discuss. 3) Guiding individual and group investigations. 4) Analyze and evaluate the problem-solving process. 5) Develop and present the work (García-Ponce et al., (2021) & Arends, 2008)

b. Experiment-Based Inquiry Learning

Experimental-based inquiry learning prioritizes the learning process through scientific experience in finding information, asking questions, and investigating phenomena that occur in the environment to find a concept or principle. The strength of experimental-based inquiry learning is emphasizing the development of cognitive, affective, psychomotor aspects to create more meaningful learning and provide space for students to learn according to their respective learning styles and can develop student learning psychology from the behavior change process thanks to the experience (Darwis et al., 2021; Chiang et al., 2021; Morsink et al., 2021; Tsivitanidou et al., 2021; Cokar et al., 2021). The effectiveness of experimental-based inquiry learning can improve science process skills, academic achievement, attitudes, concept understanding, higher-order thinking skills, concept mastery, and critical thinking skills (Darwis et al., 2021; Tekin & Mustu, 2021; Cetin, 2021; Sarioglan & Can, 2021; Levy et al., 2021).

c. Project Based Learning

Project-based learning is learning that emphasizes solving problems that occur every day through certain activities (projects). Emphasis on real problems carried out in an activity is the most important learning process in project-based learning (Miller et al., 2021). The strength of project-based learning is to train students to use reasoning in solving problems; train students to make hypotheses in problem-solving; train critical and contextual thinking skills with real problems faced; train students to conduct trials in proving hypotheses; train in decision-making about problem-solving by (a) actively participate and concentrate in discussions; (b) stimulate students to think by returning questions to them; (c) encourage students to analyze problems, synthesize problems, conduct evaluations, and compile a summary of evaluation results; and (c) assisting students in identifying sources, references, and principles (materials) while studying problems and alternative problem solving (Mahanan et al., 2021; Santyasa et al., 2021; Supriyanti et al., 2021; Matilainen et al., 2021; Barak & Yuan, 2021). The effectiveness of project-based learning can increase innovative thinking, information literacy, learning motivation, scientific literacy, and interesting learning and increase student engagement, motivation, and academic achievement (Barak & Yuan, 2021; Supriyanti et al., 2021; Miller et al., 2021; Duke et al., 2021; Maros et al., 2021; Leggett & Harrington, 2021).

d. Game-Based Collaborative Learning

Game-based collaborative learning focuses on group composition, heterogeneous versus homogeneous, group selection and size, team structure, number of teacher interventions in the learning process, gender and ethnicity, and different learning styles and the role of technology in enhancing social activities such as perception, solving problems, memory and thinking in using approaches with social action and social interaction through game-based learning activities. The strengths of game-based collaborative learning can build a frame of understanding of the problem, clarity of team tasks in solving problems, improve social interaction skills, and can produce more accountable work (Czauderna & Guardiola, 2021; Gupta & Pathania, 2021; Supena et al., 2021). The effectiveness of the implementation of game-based collaborative learning can improve metacognitive abilities and social relations (Järvelä et al., 2021& Herrera-Pavo, 2021). In addition, it can reconstruct online practices, learning experiences, and learning processes (Törmänen et al., 2021; Lämsä et al., 2021).

e. Problem-Based Learning

Problem-based learning (PBL) is a learning strategy that involves students solving a problem through the stages of the scientific method so that students can learn knowledge related to environmental problems as well as have the skills to solve problems. The strength of problem-based learning is that it challenges students to discover new knowledge, helps students transfer knowledge to understand real-life problems, and develops students' ability to think critically (Tal etal., 2021; Mann etal, 2021; Seibert, 2021; Dita, 2021). The effectiveness of the implementation of problem-based learning can improve academic achievement and critical thinking skills and abilities, learning motivation, higher-order thinking skills, self-confidence, and problem-solving abilities (Hursen, 2021; Festiawan etal., 2021; Suparman etal., 2021; Saputro etal., 2020; Simamora etal., 2017; Dewi, 2013a; Dewi, 2013b; Dewi, 2012).

The learning syntax of the CBL types compared with the CBL syntax showed that:

a) The instruction-based simulation learning stage focuses more on simulation activities to display symbols or equipment that replaces actual processes, events, or objects in learning. The CBL learning stages focus more on the orientation of certain problems or situations to find alternative solutions to problems directly. Thus, instruction-based simulation learning is not relevant to CBL learning.
b) The experimental-based inquiry learning stage focuses more on the scientific work-oriented learning process to seek and find solutions to problem-solving. The CBL learning stage focuses on solving cases from various sources of information to bring up various views and analyses developed from the resulting solutions. Thus, experimental-based inquiry learning is relevant to CBL learning.
c) The project-based learning stage focuses more on solving problems that occur every day through hands-on practical learning experiences in the field to produce work products from project activities based on the material being taught. The CBL learning stages focus on solving problems directly related to the daily experiences of students so that they are related to real life. Thus, project-based learning is relevant to CBL learning.
d) The game-based collaborative learning stages focus more on group learning both homogeneously and heterogeneously to build social interaction in the learning process. CBL learning stages require teams to collaborate in solving cases. Thus, game-based collaborative learning is not relevant to CBL learning.
e) The stage of problem-based learning (PBL) focuses on solving problems without requiring previous experience or knowledge regarding the material being taught. CBL learning requires prior knowledge to support case resolution. Thus, problem-based learning (PBL) is relevant to CBL learning.

Based on the results of the study above, it shows that CBL learning is relevant to experimental-based inquiry learning was 32%, project-based learning was 30%, and problem-based learning (PBL) was 31%. This means CBL learning is an instructional model design from variant learning models that are cognate and closely related to Problem Based Learning, Inquiry-Based Learning, and Project-Based Learning which are incorporated in the same learning system, namely active learning. The strengths of CBL learning include a) students get learning to think critically and find the right solution to a case; b) students can work together with colleagues/teachers in solving a case that is studied together; c) values of tolerance, respect for the opinions of others, democracy and objectivity of thought can be trained and developed; d) students have the opportunity to explore their potential, develop concepts and ideas; e) students gain experience by analyzing ideas and applying them in everyday life (Hong & Yu, 2017; Jamari et al., 2018; Günter & Azman, 2019).

Case Forms in CBL Learning

The form of cases used in CBL learning is factual news, complex problems are written to stimulate class discussion and collaborative analysis (Suwono et al., 2017; Garcia-Ponce et al., 2021). Cases are taught by involving students for interactive, student-centred exploration of ideas and specific situations. Cases are used as catalysts in class discussions or lectures. A student-centred discussion can become a major activity of the class as students collaborate to analyze the full dilemma and the data provided and share it in the action section. Case-based learning can also be used in small or large classes. After setting the case, the teacher can identify alternatives that might be discussed in the discussion process, then analyze them collaboratively, and then draw conclusions (Kulak & Newton, 2014; Nair et al., 2013).

The cases that are usually presented in CBL learning relate to the essence in the context of the problem. The problems found in CBL learning are in the form of story descriptions. The strengths of using story descriptions in CBL learning are: a) Stories can be used as copies of concepts, basics, and theories being taught, and are rich in examples related to students' understanding memory; b) Stories can be used as examples of cases that students must find solutions to and become good learning strategies; c) Stories can be a forum for student reflection to measure their ability to understand a case; d) Presentation of learning with story or case questions will form students' memory because they are accustomed to experiencing and understanding themselves various kinds of cases that have various kinds of solutions (Kulak& Newton, 2014). This will have an impact on students' memory of a concept that is stronger than being taught directly (Günter et al., 2019). In addition, it makes it easier to apply theory to a real context, can choose actions that must be taken, develop self-knowledge, can compare and evaluate self-perspectives with the perspectives of others (Bi et al., 2019; Jamari et al., 2018; Günter & Azman, 2019; Suwono et al., 2017; Alt et al., 2020; Günter & Alpat, 2019).

Conclusion

Based on the results of the literature review analysis on Scopus articles from 2011-2021 about case-based learning in chemistry learning. It was found that the CBL learning model is implemented in three (3) learning approaches, namely CBL in Inquiry-Based Learning, CBL in Problem-Based Learning, and CBL in Project-Based Learning which is incorporated into the same learning system, namely Active Learning. The form of case used in CBL learning is in the form of factual news presented in the essence of the problem context in the form of a story description. This literature review study implies that CBL learning can be applied in narrower cases similar to problem-based learning and can be applied in more open cases similar to project-based learning and can be applied in cases of content similar to inquiry-based learning. The recommendation for the next researcher is that in implementing CBL learning, it is necessary to prepare a case in advance according to the scope of the learning used.

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