A Conceptual Framework for Empowering Students’ Critical Thinking through Problem Based Learning in Chemistry

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Abstract. Problem Based Learning (PBL) is a model whose learning relates to problems in everyday life. Through problem-solving activities, it is hoped that it can empower students’ critical thinking skills. This paper proposes a conceptual framework to explore the implementation of problem-based learning in empowering critical thinking. This research method is qualitative research categorized as a literature review. Data collection was carried out by documentation method through the stages of searching, selection, presentation, and descriptive analysis of literature related to PBL and critical thinking. The method use is qualitative with the main source from the literature review of the PBL and critical thinking. From the results of the literature review analysis reveals the steps of the PBL model are, 1) oriented questions to problems, 2) Organize student to learn, 3) Guiding individual and group investigations, 4) Develop and Present the Work, 5) Analyze and evaluate the problem-solving process. Critical thinking skills that can be empowered through the application of problem-based learning in this article include 1) the ability to focus on questions, 2) analyze arguments, 3) the ability to ask a question and the ability to answer the question, and 4) express opinions during presentations appropriately based on appropriate learning resources, 5) observing and considering the results of observations, 6) identifying assumptions, and 7) deciding on an action. The literature review results show that the syntax contained in PBL can improve critical thinking.

1. Introduction

Learning in the 21st century demands a change in orientation in learning, namely mastering the combination of the content of knowledge, skills, expertise, and expertise. 21st Century learning also requires students to have thinking skills, action skills, and life skills. According to the Partnership for 21st Century skills, one amongst the life skills students must-have within the 21st century is critical thinking skills [1]–[6]. Tan (2004) states that in the 21st century, students need to have metacognition competencies and self-regulation as the key to improving thinking skills [7]. Also, in the 21st-century learning assessment and critical thinking skills are needed by students at the tertiary level and the work environment [8]. To achieve this competency, students must have the ability to evaluate evidence, distinguish false and true and incomplete information, and draw conclusions [9].

Critical thinking is the ability of students to analyze arguments, make conclusions using reasoning, assess or evaluate, and make decisions or problem solving [4]. Empowering critical thinking in students needs to be done so that students can solve various problems that exist in everyday life. By empowering students’ critical thinking skills, it will affect student learning outcomes [10]. The ability of critical
thinking in students can not only be seen from the ability of students to answer or solve problems but can also be seen from the ability and quality of questions asked by students.

Critical thinking is the ability to apply High Order Thinking Skills (HOTS) and an attitude of thinking that leads to logical action action [11], [12]. Students' critical thinking skills must be developed by involving students in active learning. The learning process that can involve students actively, namely by students carrying out analysis activities, synthesizing, and evaluating information to unravel problems and make decisions. To empower students' critical thinking in the learning process, an innovative learning model is needed such as the Problem Based Learning (PBL) model [13]–[17]. PBL learning model allows students to learn meaningfully which can develop higher-order thinking skills through problem-solving. Halpern (2013) revealed that students' critical thinking skills are improved through problem-solving activities [18].

Problem Based Learning (PBL) is an active learning model that uses ill-structured problems in the form of complex real-world problems as a starting point in the learning process [7], [19]. Boud and Falleti (1991) also explained that by applying PBL students in the learning process that was confronted with practical problems, in the form of ill-structured through stimulants in learning, it can increase students' critical thinking [20]. PBL may be learning that's a learning model that's quite important to be applied in chemistry learning because it can develop students' critical thinking abilities. This article provides an overview of the importance of critical thinking and its specifications and how the characteristics of PBL are seen from its relationship with critical thinking skills.

2. Metode
This research is qualitative research which can be categorized as a literature review study. The process of the literature review method in this study is [21], [22]:

- Choose a review topic
- Search for literature

The process of searching for literature by filtering based on criteria determined by the authors of each journal taken. The criteria for journal collection are as follows: 1) Compatibility of writing keywords, linkages of writing results and discussion of Problem-based learning, critical thinking; 2) Strategies in collecting journals for various literature using accredited journal sites such as Eric, PubMed, Research Gate, Sciendirect, SagePub, and Scholar; 3) Assessing the journal from the abstract whether it is based on research objectives and conducting a critical appraisal with the existing tools

- Collect, read and analyze literature
- Write a review
- Reference

In this research, the information that must be obtained is about critical thinking and the empowerment of critical thinking through PBL syntax. In the Problem Based Learning section, the writer uses the theory from Arends (2012) [23]. For critical thinking indicators, the authors use Ennis (1986) [24]. After the study of PBL and critical thinking has been obtained, the next step is to analyze the PBL syntax with the critical thinking indicator. So that from this literature review, it can be obtained that PBL syntax information can empower critical thinking.

3. Result and Discussion

3.1. Critical Thinking
One of the skills that is expected to be output in the ongoing learning process is critical thinking skills [25]–[27]. Critical thinking is the ability and tendency to make and assess conclusions based on evidence [28]. Rainbolt and Dwyer (2012) state that critical thinking is the skill of evaluating the arguments made by other people correctly and making good and correct arguments by themselves [29]. Furthermore, according to Santrock (2011), critical thinking includes thinking reflective, productive, and evaluative about an event [30]. Another definition of critical thinking according to Lipman (1988) states that critical thinking is a thinking skill that can be accounted for to facilitate making the right
decisions [31]. According to Ennis (1996), critical thinking is thinking reasonably and reflective by emphasizing making decisions about what to believe or do [32].

Based on some of the opinions above, it can be concluded that the notion of critical thinking is the ability of everyone to analyze ideas or ideas in a more specific direction to pursue relevant knowledge about the world by involving evaluation of evidence. Critical thinking ability is needed to analyze a problem to the stage of finding a solution to solve the problem. Students who are equipped with critical thinking skills can observe the right or wrong opinions of others based on scientific truth and knowledge, so that without any doubt they can decide and judge what is wrong and right.

One of the goals in science education is to develop critical thinking [31]. McKnight (2016) revealed that chemistry learning allows students to cultivate critical thinking that can be applied to other real-world situations [33]. Critical thinking skills are a concept that is embedded in studying chemistry [33] because it involves logic, depth, clarity, and accuracy. Collecting data and drawing conclusions is the basis of certain data which requires critical thinking skills. In studying chemistry collecting data and drawing conclusions is the basis for most experiments so that critical thinking is needed by students [34]. Critical thinking in chemistry requires students not only to think about concepts and principles but also how students can apply them to other fields. Critical thinking indicators are grouped into five thinking abilities. The five dimensions of critical thinking are further described in Table 1 below:

| Table 1. Dimensions and Indicator of Critical Thinking |
|------------------------------------------------------|
| **The Critical Thinking Core**                        |
| **Dimension**                                         |
| **Indicator**                                         |
| Elementary Clarification                              |
| Focus on a question                                    |
| Analyze arguments                                     |
| Ask ad answer clarification question                   |
| Based for Decisions                                   |
| Judge the credibility of a source                      |
| Observe, and judge observation reports                 |
| Inference                                             |
| Deduce, and judge deductions                          |
| Induce, and judge inductions                          |
| Advanced Clarification                                |
| Define the term, and judge definitions                 |
| Definitional Strategy                                 |
| Strategies and tactics                                |
| Deciding on actions                                   |

3.2. Problem Based Learning

Problem Based Learning (PBL) is learning designed based on authentic and open problems related to the real world, so that students compile their knowledge, develop inquiry, and develop higher-order thinking skills [23], [35]. The PBL learning model provides real problems to students so that students learn about critical thinking and problem-solving skills, train higher-order thinking including learning how to learn (metacognitive), and train students to be independent and self-regulated learners [9]. According to Tan (2004), PBL is the use of various kinds of intelligence needed to confront real-world challenges, the ability to deal with everything new and existing complexities [7]. PBL is a learning model based on the principle that problems can be used as a starting point for acquiring or integrating Barrows (1980)’s new knowledge. From some of the opinions above, it can be concluded that PBL is a problem-solving-oriented learning model that is integrated with real-life to form new knowledge or concepts so that it can train higher-order thinking skills [36].

The characteristics of problem-based learning according to Tan (2003) are (1) problems are used as starting points in learning; (2) real problems with unstructured real world; (3) problems require multiple perspectives; (4) problems, challenging the knowledge possessed by students, attitudes, competencies, which then require identification of learning needs and new fields of learning; (5) learning self-direction is the main thing; (6) utilization of various knowledge sources, their use, and evaluation of information sources are essential processes in problem-based learning; (7) the learning process takes place
collaboratively, communicatively and cooperatively; (8) developing inquiry and problem-solving skills to find solutions to a problem; (9) process openness in problem-based learning includes the synthesis and integration of a learning process; (10) problem-based learning involves evaluating and reviewing learning experiences and processes [7]. Problem-solving activities in PBL can provide opportunities for students to develop critical thinking skills, propose creative ideas, and communicate them to other friends [37].

A well-executed PBL learning model requires effort in three domains: Planning (identifying course content and determining measurable learning objectives); instruction (selecting and implementing methods to be used to deliver material and facilitate achievement of learning objectives); assessment and evaluation (selecting and applying the methods used to determine whether and how well the learning objectives have been achieved and interpreting the results. The domain can be illustrated in Figure 1.

There are five phases of the Problem Based Learning model, namely the first phase, oriented question to the problem, which is a problem scenario phase that can provide stimulus and realistic thinking so that students can express opinions based on facts that can be identified as the basis of the problem. In the second phase, Organize students to learn is a problem analysis phase to stimulate students' basic knowledge, and generate ideas that support further knowledge, identify problems with the subject of learning. The third phase, guiding individual and group investigations, is a phase that involves the process of finding and investigating through various sources of information, reporting any information found to the group through discussion activities. The fourth phase, Develop and Present the Work, is an interactive process through discoveries from learning, reporting, peer teaching, and presentations. The fifth phase, Analyze and evaluate the problem-solving process is a phase of reviewing, integrating important concepts from the new knowledge obtained, and evaluating each phase that has been carried out during the learning process [23].
3.3. Empowerment of Critical Thinking through PBL Syntax

Based on the results of a literature review on critical thinking and the PBL learning model, an analysis was carried out whether the PBL syntax in the PBL model can foster critical thinking.

3.3.1. Oriented Question to the Problem

At this stage, the teacher proposes a phenomenon or demonstration or story to raise a problem. The problems used are real, unstructured (ill-structured), and open. An example in one of the materials in chemical learning is colloids. At this stage, the teacher gives questions related to the daily life of students. The teacher asked the question have you ever drank milk. When compared to syrup and coffee, can you tell the difference? Analyze why milk is included in colloids.

![Figure 2. (a) Syrup; (b) Milk; (c) Coffee](image)

Students at this stage develop problem-solving and critical thinking skills as well as build new knowledge from the questions that have been asked by the teacher. According to Jacqueline and Martin Brooks in Santrock (2007), a way that can be done to foster students' critical thinking in learning is to expose students to topics or themes that are controversial and close to the world of students [30]. This means that learning must use themes that provide opportunities for students to think. In this syntax, the critical thinking indicator is in the form of focusing questions and answering questions that need explanation. Students learn to think gradually through habits that are trained in the form of formulating problems and answering questions that need explanation [27].

Through this first stage, students analyze through activities to identify the phenomena presented and formulate questions. Student activity in this phase is to practice formulating questions to be tested through investigation or experimentation. By doing this activity repeatedly in each meeting, students practice their thinking skills to focus on questions. The activity of focusing on questions at the beginning of this lesson has also been proven to be able to attract attention and stimulate students to empower their thinking skills through the opinions put forward. According to Ennis (1996), the focus is important to know something, by making some questions related to an event that occurs can make the mind more focused so that it can find out the main points of an event, issue, and problem that occurred [24].

In this phase, students discuss with friends in one group or with another group. In this discussion, students have the opportunity to give reasons, submit opinions, and reject or support statements from their friends. Through this activity, students analyze any information and choose the right arguments before expressing their opinions. The process of choosing the right argument is what stimulates students to practice analyzing arguments [39]. The ability to reason is trained with the habits of students formulating solutions. In formulating this solution students argue or give reasons [28], [40].

Asking questions is a core part of learning and finding knowledge. Students' curiosity as initial capital for critical thinking needs to be nurtured so that in learning the teacher does not just convey information but provokes students by asking questions with various methods so that students find their answers. According to Winn in Santrock (2007) that in addition to the theme of fostering critical thinking skills in learning, teachers must use discussion and debate methods and provide opportunities and stimulate students to ask questions [30].

3.3.2. Organize student to learn

Through this phase, problem analysis serves to stimulate students' basic knowledge, and generate ideas that support further knowledge, identify problems with the subject of learning. Through this phase, students ask for solutions or explanations about problems by asking questions. In the syntax, the three
indicators of critical thinking that are developed are building basic skills. In this indicator, students are asked to consider the credibility (criteria) of a source. The purpose of this indicator is to consider the suitability of a source. In this indicator, students are free to look for problem-solving sources from anywhere, be it books, magazines, newspapers, or the internet. Furthermore, the information is evaluated and which ones are suitable for the problem and which are not by the problem. In this case, students will practice applying the ability to select information and determine relevant and irrelevant sources. This ability is very important so that students are not fooled by useless information/sources that can interfere.

3.3.3. Guiding individual and group investigations

This phase involves the process of finding and investigating through various sources of information, reporting any information found either individually or in groups through discussion activities. In this phase, the teacher encourages students to get the right information, carry out experiments, look for explanations and solutions. Student activity during the investigation allows a thought process and exchange of opinions to find solutions to problems that have been proposed in the previous phase. Activities in this phase require being able to obtain information to report findings. The findings show the results of collaborative activities among group members [4]. In the syntax, the three indicators of critical thinking that are developed are building basic skills and concluding. In this indicator, students are asked to observe and consider the results of observations made and make inductions and consider the results of the induction. Critical thinking leads students to step out of self-deception by seeing things directly from various angles and then evaluating them through a rigorous intellectual activity process [41].

Indicators observe and consider the results of observations that can be seen when students conduct experiments by learning activities with the PBL model. On this indicator, students report their observations/experiments and are involved in concluding based on the results of the observations/experiments carried out. Students experiment. During the experiment, students observe and record important things related to the experimental results report. According to Leicester & Taylor (2010), observing activities can produce evidence empirically depending on experiments or experiments that are rooted in experiences from the real world and objects that exist in space and time [27].

The ability to induce and consider induction, to make and assess the values of the results of judgment, identify assumptions, and collate opinions is developed through the phases of analyzing data and evidence and building new knowledge. This critical thinking ability can be developed in this phase because students carry out data collection activities, interpret data, and draw conclusions based on the data obtained.

3.3.4. Develop and Present the Work

In this phase, students prepare their work to be presented. The work can be in the form of a written report or a post. Then it can be continued by displaying the work in front of other students. This phase can develop students' abilities to evaluate based on facts and provide alternative answers when other groups present the results of their discussions. The teacher's job helps students to clarify doubts. In this phase, it is necessary to pay attention to gaps and to correct misunderstandings or overgeneralizations that arise during the discussion. According to Ennis (1996) making an observation, reports is very helpful in identifying things that are seen or heard. Making good observation reports requires caution, observers are in good condition so that they are impartial, reported directly and if using technology must come from competent parties. In the syntax, the four indicators of critical thinking that are developed are to make further explanations. In this indicator, students are asked to identify assumptions. According to Fischer, assumptions are beliefs that are accepted or considered true by the speaker or writer but they do not state or make it explicit. So that in identifying assumptions, students need reasoning about an event that is presented [41].
3.3.5. **Analyze and evaluate the problem-solving process**

The review phase, integrating important concepts from the new knowledge obtained and evaluating each phase that has been carried out during the learning process. In this phase, students assess and evaluate the results of problem-solving carried out by other groups and compared with the knowledge they have to obtain appropriate problem-solving. The PBL model trains students to solve problems. In the process of problem-solving students are active in seeking and exchanging information and evaluating various information to be used in solving problems [42]. In addition to evaluating the information they get themselves to solve problems, students also evaluate the problem-solving process carried out by other groups in class discussions. Also, students are asked to reflect on themselves in the problem-solving process. Students are asked to reflect on the solution and explanation of the problem that has been solved. In the syntax, the five indicators of critical thinking that are developed are strategy and tactics. In this indicator, students are asked to decide on an action. This indicator aims to select criteria for considering possible solutions to the problem. The ability of students to analyze the problem-solving process will determine the level of critical thinking skills because analyzing is an intellectual process to choose the right solutions. According to Fischer (2008) several things need to be considered in making decisions so that the decisions taken are the right ones, namely; consider possible alternative courses of action, consider the possible consequences in the various alternatives, consider how likely/impossible and how valuable the possible consequences, consider appropriate commitments and finally consider which alternative is best viewed from consequences [42].

Through PBL syntax students not only master material or concepts that are easily forgotten but can analyze and understand their meaning and acquire skills in solving problems. This is by the opinion of Arrends (2008) that the PBL model is a learning model that can help students to improve critical thinking abilities and problems solving abilities [26]. The PBL model can support the student to improve critical thinking in terms of the phases of their learning model [43–45].

4. **Conclusion**

The PBL model has the potential to empower students' critical thinking because students are stimulated by the way they think through problems that exist in everyday life. The problems given are open so that problem-based learning can provide opportunities for students to explore and collect complete data in solving problems. With the PBL model, the learning process is oriented towards authentic problems, and students are not only asked to understand a problem but must also be able to work together to solve the problem, to stimulate students' abilities, especially critical thinking skills. Students' critical thinking skills can be developed in the learning process through the learning syntax of the Problem Based Learning model. The PBL syntax is 1) oriented questions to problems, 2) Organize student to learn 3) Guiding individual and group investigations 4) Develop and Present the Work, 5) Analyze and evaluate the problem-solving process. With the PBL model students are trained to be able to study or analyze a source, identify relevant and irrelevant sources, identify and evaluate assumptions, apply various strategies to make decisions. This can be seen from the stages in the PBL model which constructs students' knowledge and experience so that students can reason and develop critical thinking skills.

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