INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 13, Issue 4, (2024) E-ISSN: 2226-6348

Exploring the Perception and Understanding of Malaysia Public University Lecturers on Critical Thinking Skills in Chemistry Using Facione's Critical Thinking Model

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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v13-i4/23796 DOI:10.6007/IJARPED/v13-i4/23796

Published Online: 27 November 2024

Abstract

Teaching and learning critical thinking skills is not a foreign concept in education, especially in tertiary education. This study investigates the perception and understanding of Malaysia public university lecturers on critical thinking skills in chemistry. A semi-structured interview was conducted on three chemistry education lecturers, selected using purposive sampling. The interview transcripts were then analyzed to form themes for the study. The findings show that interpretation, making inference, analysis, evaluation, explanation, and self-regulation is suitable for chemistry.

Keywords: Critical Thinking Skills, Chemistry, Perception, Lecturer

Introduction

Critical thinking is one of the important learning skills in 21st century learning. Cultivating critical thinking enables students to analyze information, evaluate evidence, and construct reasoned arguments. These skills empower students to engage in reflective and independent thinking. The essence of critical thinking lies in questioning rather than accepting information at face value and encourages into the 'why' and 'how' behind facts and ideas, therefore, leads to a deeper understanding of subject matter. Findings by Anggraeni et al. (2023), found that 67% of studies on critical thinking using problem-based learning approach are conducted in higher education. 49.93% lecturers in Indonesia understand the advantages or importance of students' critical thinking skills (Amin & Adiansyah, 2018). A study by Jerome et al (2019), on Malaysia lecturers' perceptions on teaching strategies that could enhance higher order thinking skills shows that many lecturers believed that lecture and discussion can enhance higher order thinking skills. However, there is no mention of their understanding on what constitutes critical thinking.

Chemistry stands out as a field where critical thinking is not only beneficial but rather essential, giving its reliance on practical application, hypothesis testing, experimental evidence, as well as theoretical application, therefore demands reasoning and evaluation that goes beyond memorization of facts. Critical thinking in chemistry involves the application of logic and reasoning to understand chemical phenomena, solve complex problems, design experiments, and interpret data. For example, understanding the principles of acid and base requires more than memorizing the chemical formulae, but critical thinking allows students to analyze the reason why water is formed when acid reacts with base. In order to prove the reaction, students must conduct an experiment. Again, critical thinking is essential for analyzing results, discerning patterns in titration curve, and drawing conclusions to test hypotheses while controlling the variables. These processes utilize critical thinking skills such as making inference, analyzing, and evaluating which are among the cognitive skills of critical thinking proposed by Facione in 1990 using Delphi method where consensus from experts from various disciplines had been taken place. Facione's critical thinking model encompassed a broad spectrum of critical thinking skills. They are interpretation, analysis, inference, evaluation, explanation, and self-regulation (Facione, 1990, 2015).

These components allow for adaptation to the specific needs of different disciplines, including chemistry. This is because the skills are relevant to scientific methods such as hypothesis testing (inference), experiments (analysis), and data interpretation (evaluation). In short, Facione's framework directly aligns with curricular goals, particularly in chemistry where students are expected to analyze data and suggest improvements, explain the findings from their experiments, interpret relationship between two categories, as explained in *Dokumen Standard Kurikulum dan Pembelajran, Kimia* (Ministry of Education, 2018). Therefore, this research aimed to explore and understand critical thinking skills in chemistry according to chemistry education lecturers.

Methodology

This is a qualitative study to explore and understand how lecturers perceive and understand critical thinking in chemistry. Three public university lecturers participated in the study and were chosen by purposive sampling, based on the criteria that they are chemistry education lecturers in public university, have taught for more than five years, and also committed to involve in the study. The details of the respondents are shown in Table 1 below.

Table 1
Details of the Respondents

Code name	Institution	Expertise
R1	Public university A	Chemistry Education – Blended problem-based learning
R2	Public university B	Science Education and Classroom assessment
R3	Public university C	Chemistry Education and Curriculum Development

Data was collected using semi-structured interview conducted in English, with each session lasting for 60 minutes using Google Meet due to demographics of each respondent. Interviews were transcribed, then categorized to form themes using template analysis and sent back to the respondents for member checking process and then to other experts from two different university for peer review process to ensure validity of the findings. Triangulation was used to corroborate findings from other sources and fill gaps in research (Bowen, 2009; Morgan, 2021).

Results and Discussion

In this section, the findings from the semi-structured interviews with the respondents are presented and analyzed below;

Perception of Critical Thinking in Education

In order to understand respondents' perception on critical thinking, a question of "What is your perception of critical thinking in education?" was asked. R1 stated, *"Critical thinking, OK, to cut it short, in the layman sense… critical thinking is just the ability of students to give a justification of his or her answer. And then the ability for him to give the justification based on the evidence that he or she has."* R1's answer shed some light on how some educators perceived critical thinking. "Focus on justification" suggests that within educational context it's not just about arriving at answer but also lies in understanding the 'why' behind the 'what'.

Coincidentally, R2 shared the same sentiment. *"I trained teachers, I trained chemistry teachers. So, I always tell my students, if you can listen to your students and even if they give you a correct answer, always ask why. And the students can reason it out. OK, why I'm getting this answer and if they can simplify things, I think that is critical thinking, you know."* R2's statement suggests that teaching methods should focus on asking students "why" even after a student has given a correct answer. By asking "why", this encourages students to actively question and explore concepts, thus promoting a culture of inquiry and develops reasoning and justification skills. Moreover, in teaching students to justify their answers, teachers are able to assess the validity of students' assumptions, the strength of their arguments, and the reliability of their evidence, which also mentioned by R1 with this statement, *"to give the justification based on the evidence that he or she has."* The emphasis of evidence when providing justification shows the need for arguments to be based in credible information. This elevates the quality of an argument and ensures that conclusions are drawn based on supporting information.

R3 shared the sentiments. *"Well…because we are in science, we need this skill. It's a skill where the students need to think deeply about something like when we give them a scenario or a situation so they have to think about it and…um…justify, somehow make reasoning… like they have to come up with a scientific reasoning if we look at the sentence, so they don't just simply accept…the evidence, they can't simply accept what they hear. They have to perhaps…investigate, they have to investigate and then and then they have to justify, and also they have to give reasons, you know…why? why it is like this…let's say they are doing an experiment and also they have gather the evidence, they have to somehow justify the findings, they have to provide reasoning. So I think that's how we have to think critically."*

R3 began with the acknowledgement that critical thinking is necessary in science (and by extension chemistry), highlighting the need for students to think deeply about something when given a scenario or situation. This shows that learning science is not just about learning facts and figures but involves a deeper engagement with content. Similar to R1, R3 believed that critical thinking is not about taking things at face value but rather emphasis on justification and reasoning with the presence of evidence. Moreover, in chemistry, investigation is a core aspect of scientific inquiry and requires students to design and conduct experiments, observe phenomena, and collect data. Therefore, this process requires students to actively analyze the information or data and making conclusions, which encourage students to actively seek out answers through evidence and reasoning. Based on the discussion above, all three respondents believe that critical thinking is about giving justification to their reasoning, and it should be supported with evidence. The next question is, how to apply critical thinking?

Application of Critical Thinking in Daily Life

Below diving further into the application of critical thinking in chemistry, let's dive into the application of critical thinking in daily life to get a general sense of critical thinking skills. R1 described the application of critical thinking in daily life*"We always apply critical thinking in our daily life whether we realize it or not. And then when we are deciding something. OK. For example, I'm deciding to buy something. OK. I want to buy shampoo. So, I did a critical thinking actually when I think the best shampoo for me, OK. For example, I will analyze. One of the elements in critical thinking is analyzing, right? So I had the ingredients of each shampoo that I shortlisted, right? I analyze it. OK. I have compared it, and I will reflect back. OK, which shampoo is the most suitable shampoo for me. For example, I have very sensitive skin. And so I will choose the shampoo that has that kind of ingredient for the sensitive skin and then you have the, what I call that a hair fall problem. OK, maybe I will choose the shampoo that has the ingredient that specifically okay to treat the hair fall problem among the users. OK. This is what they call reflection. OK. You want to reflect it back when you have chosen something or in this case when I chose the shampoo."*

According to R1, critical thinking is not reserved for complex problems in academic settings, but it is something that humans have been doing in everyday life. The insight from R1 illustrates how critical thinking is being used during everyday decision-making processes, often subconsciously without explicit acknowledgement. A seemingly mundane activity, which is choosing a shampoo, shows how critical thinking can be used in everyday scenarios. The process encompasses various elements of critical thinking such as analysis, evaluation, and reflection.

Analysis: The act of analyzing the ingredients of each shampoo. R1 does not only look at the list of each ingredient in the shampoo, but also understand the implications of each ingredient and how it concerns one's specific needs such as sensitive skin or hair fall issues. This step requires data gathering (reading and listing out ingredients) and breaking it down into understandable parts (understanding the implications of each ingredient).

Evaluation: Comparing each option based on ingredients to determine the effectiveness of the ingredients for the specific conditions.
Reflection: Reflecting on the choices, involving reviewing the reasoning process and the evidence considered.

The example above shows the importance of honing critical thinking skills, as it improves decision-making and problem-solving skills across all areas of life. It also serves as a reminder that fostering critical thinking can enhance the quality of decision making and lives.

Application of Critical Thinking in Chemistry

In order to explore the cognitive skills of critical thinking in chemistry, this question was asked to the respondent, "*What are the cognitive skills of critical thinking in chemistry?"*

Facione's critical thinking model identified six key skills. They are interpretation, analysis, inference, evaluation, explanation, and self-regulation.

Interpretation

R1 believed that interpretation *"portray your understanding towards some concept when you are doing chemistry"* and further elaborated "*Interpretation is a judgement by using experience in one situation. For example, the concept as acid and base concept, right? Interpretation is you show how you understand this kind of concept, what is your understanding about the concept, the criteria of the acid; "Acid is blah blah blah blah blah," and then what is the use of acid? We just show to others our understanding towards the concept that has been asked."* According to Facione, interpretation involves the ability to comprehend and express the meaning or significance of a wide range of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria. In the context of the excerpt, the process of interpreting a scientific concept (acids and bases) requires students to articulate their understanding of the concept. This includes defining the concept ("Acid is blah blah blah…") and explaining its applications ("what is the use of acid?"). This aligns with Facione's description of interpretation as it involves both understanding the concept's criteria and expressing this understanding in one's own words. Furthermore, by explaining acids and bases, by defining them, discussing their uses, and explaining these ideas to others shows deeper conceptual understanding on the subject matter.

R2 explained the concept of interpretation in chemistry as follows, *You know…when you talk about bondings, you can actually explain why some bonding are weaker and some bondings are…bigger, stronger?"* The focus of "why" in the excerpt encourages a move from surface-level knowledge to a deeper investigation on the principles and causes in bondings, showing a comprehension and understanding with the concept of chemical bonding. At its core, interpretation requires a deep understanding of the subject matter. This phenomenon aligns with the study conducted by Dosinaeng (2019), where the subjects were asked to interpret the given problem in combinatorics problems. Those with the ability to interpret the problem correctly were able to determine the meaning behind the problem and later were able to analyze and evaluate the problem correctly. Likewise, the subject could explain what they know correctly (Mastuti et al., 2022).

Analysis

Analysis is important in chemistry. R1 described analysis *as "The brief idea of analysis is… where you chunk the information, or… your understanding, from one part to another part. OK, for example, analysis in one problem. You chunk the problem. The first problem, the second problem, the third problem and what will you do to solve the whole problem in a big problem they have been given,"* is aligned with the definition in Dokumen Standard Kurikulum dan Pembelajaran (Kimia). According to the document, Analysis is "breaking down information into smaller parts to understand more deeply about it as well as the relationships between the parts" (Ministry of Education, 2018, page 6). This process involves breaking down a complex problem into smaller parts. This approach allows for more detailed examination of the problem's components, making it easier to understand the overall structure and how the parts relate to each other.

Based on the excerpt above, finding the inferential relationships among ideas, descriptions, or other forms of expression is important especially in chemistry. This means taking a look at experiments or chemical reactions closely. This helps understand the problem better, therefore, finding the best solutions.

Meanwhile, R2 discussed the role of analysis in the context of application; scientific experimentation of reading a thermometer, "*A simple thing I can give you, like reading thermometer for 20 minutes…you know, what gives me the right not to stop at 15 minutes? Why can't I stop at 25 minutes. So how would I know that my experiment is over already? How do you know that it will not go up for another 5 minutes, or another 10 minutes? Or the students can see, look the temperature is getting higher, and eventually it goes down and reaches the room temperature. You know, they can look for patterns like in that sense, "Oh, the temperature is going down" so they're analysing the data. I think analysing skills happens a lot when doing experiments and writing a report.*

In the context of the excerpt, R2 believed that Analysis happens during experiments. When students note the temperature decrease and relate it to the experiment's progressions based on this line, "Oh, the temperature is going down," they are actively engaging in data analysis by recognizing and understanding patterns in data and synthesizing the information in order to draw conclusions. These steps show how analysis is applied in scientific experimentation. Meanwhile, R3 believed that analysis involves an act of determining correctness or incorrectness of something, "*I think when we analyse something, we want to figure out whether this is correct or maybe incorrect."* This insight is especially important in chemistry because apart from theoretical knowledge, chemistry is inherently experimental, relying on laboratory experiments or scientific inquiry to test hypotheses, observe chemical phenomena, and gather empirical data. By comparing experimental data, chemists can confirm or adjust their models.

Inference

According to R1, inference is the process of drawing conclusions from available data or observations, *"Inference is just like we did our experiment… OK, we just draw the conclusion, or we just draw a basic conclusion or early conclusion towards the question when asked. And then inference needs to be justified."* Meanwhile, R3 offered a similar view, *"When we do inference… I think inference is, how you conclude something…how you conclude something based on your evidence, something like that."* In chemistry, inference is a process in which chemists interpret data, draw conclusions from experiments, and develop hypothesis. R1 and R3's insights emphasized that inference in chemistry is about constructing a logical narrative from empirical evidence. R1 described inference as drawing or early conclusions, which then justified. Similarly, R3 viewed inference as drawing conclusion based on evidence. The insight from R1 and R3 shows the need to encourage students to draw and justify conclusions from experimental data to foster a deeper understanding of chemistry.

Evaluation

When asked about how they understand evaluation, R1 stated that, *"Evaluation is you have to think. You need to think of what you have clarified. I think you need to…you know when there are a lot of solutions, you need to evaluate which solution is the best solution, if it's better than others, with a certain criterion maybe."* R1 pointed out that evaluation is all about the effort to thinking and looking at the information at hand. Then, R1 talked about an instance when there are many answers to choose from. In which evaluation would eventually take place when comparing which answers is the best, similar to R2's insight,*"Solving problems and then looking at the solutions that you have and seeing... OK, which solution is better, in which term it's better. Sometimes you have two solutions and both of them are equally good. But you might need to recognize in this context (of the problem) this would be a better solution."*

This is especially true in chemistry where there are multiple hypotheses or methods that might be suitable to use, therefore, the best one needs to be selected based on certain criteria. R3 further added the need for evidence when making an evaluation, *Evaluation is more to umm…kind of judgment… It is like this…usually you evaluate after you already have the results, okay, so you evaluate whether your reasoning…is it correct or not. You know, like you make the evaluation or make a judgment. But there must be evidence."* The perspectives of the respondents on evaluation enrich the understanding of evaluation in scientific inquiry. After all, chemistry is a discipline that relies on empirical evidence to corroborate knowledge or method, which demands an approach to evaluation.

Explanation

According to R1*, "Explanation…in my own personal view, when you have analyzed, when you have evaluate, the you will explain it… To explain "why you decide the solution should be A, not B?"* R1 articulated that explanation rooted from critically engaging with the information, through analysis and evaluation. R1 further elaborated by giving an example,*"For example, why do we need to cover the mercury that comes from the thermometer that has been broken? Why we need to cover the mercury with maybe…soil? Why? We need to explain it. Okay, first, we need to analyze mercury, the characteristic of mercury, because it is harmful, it can be absorbed by the vein and so on…. Since the mercury can be absorbed by the vein, so we use soil in order to trap the mercury. In order for us to explain about our solution, we need to involve a lot of thinking skills."*

In the context of chemistry education, the importance of explanation can be seen by the example above. The scenario shows the rationale for using soil which shows understanding on the properties of the mercury, the risks it possesses, and therefore being able to come up with suitable solution to prevent harm. R2 shared similar perspective regarding explanation by stating that, *"For me, they (students) are able to provide reasons for any explanation they gave... if you ask students and students can give reasons for it, and there's a flow for it, there is an understanding, the student clearly understands the concept. That's critical thinking."*

R3 added another depth to the insight. *"When you explain, you justify…the information. When you explain you also maybe use some reasoning. You want to convince… "this is the correct method, so this is the step I get after I've done the experiment." You can* *explain verbally, or you can explain using words, graphs…there are a lot of ways when you communicate the result."* The use of various form of explanation suggests that explanation is not bound in one single form, but rather have various forms and ways, for example *"…text? They can change it into a graph, they are able to provide reasons for any explanation they gave."* A critical thinker is not only able to grasp the information, but also reason and justify it in various forms of communication. Furthermore, the ability to explain shows deeper conceptual understanding of the subject matter (Rodriguez & Towns, 2019).

Self-Regulation

Being aware is the first step of self-regulation, which acknowledging one's own cognitive strength and limitation (Prather et al., 2020). R1 believed that students with self-regulation will do their best to solve problems well. *"For example, they are investigating a project or a problem. They will list down what they know about the concept, the problem and what they don't know, they will evaluate, they will analyze the problem in order for them to solve the problem. So when they are able to list down or they are able to detect or they are able to identify something that is lacking, they will look for that kind of thing, at last they will find a solution, the best solution."* R2 shared the same sentiment by musing that *"... Evaluate, self-evaluate your experiment and think about where your mistakes and can you explain to your friend why you think that this could be a mistake you make…"*

Having self-regulation means that students can identify errors and learn from mistakes. The ability to reflect the mistake would allow the students to correct the mistakes done previously and ensure to solve problem successfully (Mastuti et al., 2022). R3 added depth to self-regulation by stating that honesty is crucial. *"For example, let say I have done some research…you know, I want to report my findings, for example. So, I need to…be honest…I mean like I cannot manipulate my data, something like that. So I think, when you have self-regulation, I think you act appropriately."* This is especially true in chemistry because data should not be manipulated to ensure the accuracy and truthfulness in the findings. Furthermore, self-regulation in learning involves students taking control of their learning process, including planning, setting goals, monitoring their progress, and evaluating outcomes (Olakanmi & Gumbo, 2017). By engaging in self-regulation, students become more aware of their though processes (metacognition), which helps them to think critically.

Overall, the above responses reveal the depth of critical thinking skills in chemistry perceived by lecturers. Findings by Amin and Adiansyah (2018) shows that 38.90% lecturers in Indonesia understand indicators used to evaluate students' critical thinking skills, and in average, 27.05%, 31.40%, 42.42%, 25.57%, 53.86%, and 22.88% lecturers help students practice their interpretation skills, analysis skills, inference/conclusion drawing skills, evaluation skills, and self-regulation skills, respectively. Integrating critical thinking skills into the curriculum will ensure that students develop a well-rounded set of cognitive abilities and better prepare students to make informed decisions and navigate complex problems. This is because these critical thinking skills are interrelated, where the ability to interpret problems is the base for critical thinking skills, while students with good ability to interpret problems can analyze, evaluate, and explain problems better. Furthermore, students with good self-regulation can examine and identify their mistakes, therefore they can revisit the problems and improve their problem solving, therefore, producing a better understanding and solution for the problem (Dosinaeng, 2019).

Conclusion and Limitations

Respondents' perception on cognitive skills of critical thinking shows a deeper view on the application of critical thinking skills in chemistry. The findings show that critical thinking skills such as Interpretation, Analysis, Inference, Evaluation, Explanation, and Self-Regulation are well suited to be taught in chemistry lessons. Furthermore, it shows that Facione's critical thinking model is also well suited to be integrated in chemistry, despite a much more generic critical thinking skill; self-regulation.

While this study provides insights into the perceptions and understanding of three public universities lecturers on critical thinking skills in chemistry, several limitations should be acknowledged. The most significant limitation of this study is the small sample size, therefore the findings may not be generalizable to a broader population. Furthermore, the focus solely on the perceptions of lecturers regarding critical thinking skills in chemistry, without considering the view of students or administrators. Therefore, the findings may not provide a comprehensive understanding of critical thinking skills in a broader context.

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