Integrating Critical Thinking in Teaching Engineering Subjects for Malaysian Technical Schools Lessons

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Abstract
Critical thinking ability as one of the Higher-order thinking skills plays an important role in the development of an engineering student. A preliminary study done on Malaysian technical school teachers found that there is an issue in teaching it as a skill in lessons. Thus, a study was conducted to find out how to implement critical thinking to teach Engineering subjects in Malaysian Technical Schools. The focus was on how it should be infused into lessons and what skills students should exhibit. A qualitative approach under the case study design was utilized for this study. An open-ended semi-structured interview was conducted with six samples and was analyzed using the Miles & Huberman (1994) qualitative data analysis procedure. The result shows a need to create an environment that triggers critical thinking needs in lessons for implementation. There are also 15 abilities or constructs that can be exhibited by students to show that critical thinking is embedded in the lessons planned.
Keywords: Critical Thinking, Engineering Subjects, Teaching Approach, Malaysian Technical School, Student Ability.

Introduction
Critical thinking encompasses several key skills, including analysis, synthesis, and evaluation. Analysis involves breaking down complex problems into their constituent parts and identifying their interrelationships. Synthesis involves generating new ideas or solutions by incorporating new information or combining existing elements in novel ways. According to Dwyer et al (2014), Critical thinking is a cognitive process that involves analyzing and

evaluating information and arguments systematically and logically. It requires the ability to think independently, question assumptions, and consider alternative perspectives. By utilizing sub-skills such as analysis, evaluation, and inference, individuals can effectively assess the validity and soundness of an argument or solution. Another definition of critical thinking, proposed by Qiao (2009), highlights its similarity to scientific thinking. The scientific method, characterized by defining a question, gathering information, forming hypotheses, conducting experiments, analyzing and interpreting data, drawing conclusions, and retesting, shares similarities with the earlier definition of critical thinking. Although these definitions may seem distinct, they both emphasize the importance of analysis, synthesis, and evaluation in critical thinking. These skills are fundamental to problem-solving in engineering and other disciplines.

Accreditation bodies such as The Accreditation Board for Engineering and Technology (ABET) advocate for including communication skills, global context understanding, and critical thinking in the engineering curriculum (Gunnink & Bernhardt, 2002). Various approaches have been proposed to incorporate critical thinking into engineering education. Group discussions, forums, and brainstorming sessions can foster critical thinking by encouraging students to explore different perspectives (Radzi et al., 2009; Jacob et al., 2009). Jessop (2002) suggests a course that combines brainstorming and critical reading, wherein students tackle real-world problems and evaluate journal articles. This approach emphasizes both synthesis and analysis, promoting critical thinking skills. Alkhatib (2019) shared that Engineering education and training systems need to adapt to better prepare future engineers for the flexibility, critical thinking, and creative skills needed, Opportunities in new and value-adding ways should be seized to build a strategic vision for the future. and reduce the length of this text and refine the text to make it clearer and more concise.

The lack of research on how to integrate critical thinking into the teaching of engineering subjects in Malaysian technical schools is a significant problem. Critical thinking is crucial for students to succeed in today's world, as noted by Jalal (2017) and emphasized by (Al Qassim, 2017). However, the UNESCO review (2013) highlighted that teachers in Malaysia lack understanding and knowledge of classroom practices that align with the curriculum's philosophy and objectives. There is a need to investigate whether educators in Malaysia are prepared for the shift towards 21st-century learning, as there is a lack of empirical studies on teachers' promotion of higher-order thinking skills (HOTS) in Malaysian classrooms. According to bin Sharjudeen et al (2023), there is still a lack of understanding in integrating higher-order thinking skills in lessons among technical school teachers. This highlights the need for further research and development in this area to ensure that students are equipped with the critical thinking skills necessary for success. To explore this issue specifically in engineering subjects taught in Malaysian technical schools, research was done to answer these questions

i) How should critical thinking be infused into Malaysian technical school's engineering subjects teaching and learning approaches?
ii) What are the abilities that students should showcase to exhibit Critical thinking skills?

Method

To conduct this research, a qualitative approach using the case study design was adopted. This approach allows the researcher to delve deeper into the issue at hand.

According to Cresswell (2009), qualitative research is a process of understanding that explores social problems, analyzes words, and presents detailed views of informants in a natural manner. Cresswell (2009) also defines a case study as an in-depth analysis of one or multiple cases, which is a commonly used approach in qualitative research.

The participants in this study were selected based on their expertise in higher-order thinking skills and their role as curriculum developers for engineering subjects in Malaysian technical schools. There were six participants in total, each given a pseudonym with codes R1, R2, R3, R4, R5, and R6. These individuals were chosen because of their knowledge and experience in the field of higher-order thinking skills or their involvement in developing the curriculum for these subjects.

Table 1 provides the profiles of the participants, detailing their backgrounds and qualifications. The researchers used purposive sampling to select the participants for this study. Purposive sampling is a method commonly used in qualitative research, as it allows researchers to specifically target individuals who possess the desired expertise or characteristics for the study (Creswell, 2009). In this case, the researchers were interested in gathering insights from experts in higher-order thinking skills and curriculum developers, making purposive sampling an appropriate approach.

Table 2.1
Participant's profile

Code	Designation
R1	Expert
R2	Expert
R3	Expert
R5	Expert
R6	Curriculum developer

Interviews were used to obtain the data for the research. According to Wilkison and Birmingham (2003), an interview is a way of obtaining detailed information about a topic or subject. For this research, a semi-structured type of interview was used. Wilkison and Birmingham (2003) state that questions in this type of interview are pre-determined; nevertheless, it remains flexible where researchers are allowed to ask follow-up questions. The interview protocol was checked by two lecturers from the faculty of education at UTM to ensure the content validity. Before the interview starts, the participants are shown the protocol so that they understand what is expected from the interview session. They are also allowed to clarify if they are unclear with any questions.

Data condensation is the first step in the data analysis process according to Miles, Huberman, and Saldaña's (2014) procedures. It involves selecting, focusing, simplifying, abstracting, and/or transforming the data that are present in the full corpus of written field notes, interview transcripts, documents, and other empirical materials. In this particular

study, the researcher carefully listened to the interview records and transcribed them based on the categorical questions. This step helps to organize and make sense of the data before further analysis.

Next is the data display stage. According to Miles et al (2014), data display is an organized, compressed group of information that allows conclusion drawing and action. During this phase, all the data are designed to accumulate organized information into an instantly accessible, condensed form to allow the analyst to see what is taking place and justify either conclusions or move on to the next-phase analysis (Miles & Huberman, 1994, p. 11). After finishing data reduction and data display, the last step in the analysis is concluding. In this step, a conclusion of the results was drawn based on the research problems. The results of the interview data were compiled using themes and sub-themes.

Findings

To find out the ways to infuse critical thinking in the lessons, the respondents were asked how critical thinking should be infused in teaching and learning approaches. The participants mentioned these

Table 3.1
Findings on approaches to critical thinking

Respondent	Response	Approaches to Critical Thinking.
R1	..so macam mana nak infuse critical thinking dalam kita punya pengajaran..bagi saya ada banyak cara ya, sama ada nak guna strategi ke,steps ke, pendekatan ke tools ke, there are many ways to infuse or embed this critical thinking dalam kita punya pengajaran. so di sini, mungkin saya akan guna 5 ways to develop critical thinking ya.. so antaranya ialah, all these ways boleh tingkatkan kebolehan untuk berfikir secara critical. Antaranya, you have to became.. be self aware, kemudian faham proses pemikiran, praktis juga active listening, kerap bertanya soalan-soalan yang berkualiti. kerap juga melakukan analisis. dan buat penilaian. so penilain itu penting dalam critical thinking because bila kita cakap tentang critical thinking, kita takkan lari dari analyzing dan evaluating, because eventually, through evaluation process, we will make decision..so inilah keputusan saya, inilah keputusan yang akn menjuruskan kepada penyelesaian masalah saya pada hujungnya.	Thinking tools Critical questions

R2	…kita kena create kan aktiviti itu atau task itu memang yang masa di student itu perlukan 'do analysis', do evaluation','do synthesis… …ask them to do a comparison, using alat berfikir. For example macam concept map ke, peta minda ke, supaya dia boleh present kan similarities atau comparison… ..untuk kita nampak yang dia gunakan critical thinking ini dalam task kita…	Problem-based learning Thinking tools Investigation Argument
R3	…it's a must. You need to create the fact, into something that people can think through, by questioning, and then, from that situation, it can create another activity which is called discussion. We give the facts, we create questions, and then there's discussion, and then there's a debate and argument. but the person who is the knowledge center, dia must be resourceful la. then we need to clarify, we need to investigate and then we make a decision with consensus…	Problem-based learning. Investigation. Argument Critical questions
R4	…If you haven't asked (students to find materials), you can't say how, then you will fail, then you will start to say that it is too high of a standard for them. No! you have to relate. …. If you have not introduced anything yet, you can start with a picture of a river(example) and become to a critical height, then you can say what is going to happen if the rainfall in one more hour. So it is using critical thinking and also using any media. So that is why, learner's readiness is penting, and this is learner-centred approach,how to prepare the students to have the skills of creativity(example). that's the most important… …To summarize, to infuse semua elemen ini, bergantung kepada 1. pemahaman gurru terhadap apa yang mereka perlu ajar(take 1 knowledge first) 2. learners attribute dan learners readiness. Dan juga perkara yang paling penting ialah lesson plan into mereka infuse sahaj HOTS dalam	Problem based learning. Argument Critical questions

	teaching dan learning approach…	
R5	First.. to enhance higher-order thinking skills..but to complement this enhancing of higher-order thinking skills will be educators to know how to infuse the higher-order thinking skills into content instruction…. …if you want your teachers or educators to really infuse HOT skills, educators must be exposed to one pedagogical approach called thinking-based learning. Only then, they will know how to infuse HOT Skills into content instructions. Otherwise, if they depend on PBL alone, students will only be able to work on the task which is guided only by the materials provided to them to enhance their thinking skills. but they don't know what thinking skills they are using when they apply a certain problem.	Thinking based learning Problem-based learning
R6	..memang kita promote cikgu laksanakan projek dan dilaksanakan uji kaji. Pada saya kat daripada situ je kita boleh bincang, kita boleh mencapai nak, nak apa Critical thinking and problem solving nak ada, kat situlah tempat kita akan dapat budak punya keupayaan kan untuk menjemput untuk menzahirkan apa yang ilmu dia ada.	Problem & Project-based learning Investigation

Based on the responses yielded by the respondents, there are many ways in which critical thinking can be infused into lessons. Nevertheless, there are several approaches repeatedly mentioned by the respondents. Based on the responses by R2, R3, R4, R5 and R6, there is a need to set up a situation or problem to induce critical thinking in lessons through problem-based learning. This paves the way for a lot of other approaches while R5 also emphasizes the implementation of thinking-based learning. According to R1, R3, and R4, asking critical questions also serves as an approach that induces critical thinking in lessons. To top that up R2 R3 R4 R6 believe that arguments and investigation should be embedded in the teaching approach to further drive student's capability to think critically during lessons. To further back the teaching and learning session, R1 and R2 suggested that thinking tools such as mind mapping, concept mapping and thinking strategies should be embedded in the lessons.

During the interview, the respondents were also asked about the attributes that students should exhibit when critical thinking is infused in their lessons. They were asked based on their expertise on what and how critical thinking qualities can be observed. The responses are as follows.

Table 3.2

Findings on constructs for critical thinking

Respondent	Response	Constructs
R1	untuk menjawab soalan yang ini adalah students are able to do analysis.able to do interpretations, inference, able to explain… they have self-regulation, they are open minded, and kemudian are able to solve problem lah…	Analysis Interpreting Inference Able to explain Self - regulation Open-minded Problem-solving
R2	…kebolehan dia dia boleh buat perbezaan, buat persamaan. boleh buat analisis, boleh buat penilaian, boleh buat conclusion, boleh criticize… ..Dia critize tu, buat persamaan dan perbezaan tu guna logical thinking lah.. and dia boleh buat conclusion…	Analysis Evaluation Conclusion Criticizing Logical thinking
R3	..acceptance. they can accept differences without any conflict… ..bila ditanya soalan, they must be resourceful, in gathering and explaining al sorts of information…	open-minded Resourceful Communicate ideas
R4	…Embedded in critical thinking are skills like analysis, reflection, evaluation, and metacognition.these are higher order thinking, embedded in critical thinking…	Analysis Reflection Evaluation metacognition
R6	…maknanya kalau kalau saya boleh simpulkan apa yang nak nampak daripada student supaya dia boleh tunjuk yang dia dah belajar ketika ini satu dia boleh selesaikan masalah. Lepas tu dia boleh uruskan projek. Maknanya dia ada elemen apa nama tu organizing dia boleh organize. Lepas tu Dalam masa yang sama komunikasi kena ada, planning, compution thinking of kita bagi…	Problem-solving Management Organization Communicate ideas Planning Computational thinking

Based on the responses, it was found that several attributes can be seen exhibited by students after undergoing critical thinking-based lessons. Analysis is the most mentioned ability which was noted by R1, R2, and R4. Problem-solving capability was also mentioned by R1 and R6 as one of the critical thinking sub-abilities. Being open-minded was also one of the qualities mentioned by R1 and R3 as an ability exhibited by critical-thinking-abled students. Other abilities mentioned by the respondents was interpreting, making inference, having self-regulation, being capable of concluding, criticising, being resourceful, able to manage, organize, and communicate ideas, planning, logical thinking, metacognition and evaluating.

Discussion

Based on the results of the interview, it is clear that critical thinking is an element that can be integrated into the teaching and learning of engineering subjects in Malaysian technical schools. All respondents agreed that there must be a planned approach being set up in integrating critical thinking as part of the lesson. problem-based learning was found to be one of the most suggested teaching approaches in this matter. This is supported by Seibert(2021) who discussed that Although Problem-based learning is not a new teaching strategy, it is an ideal, evidence-based, option to fill the skill gaps regarding critical thinking and perseverance as well as accentuate Generation Z's strengths. Ali (2019) states that PBL can be united into any learning situation where Critical thinking skills, problem-solving abilities, and communication skills are the outcome of Problem-based learning

The importance of imparting knowledge on topics before engaging in critical thinking exercises is emphasized in this statement. This is further clarified by R4 which emphasizes that student readiness is very important before a critical thinking approach is employed. The readiness of students is also highlighted as a crucial factor in employing a critical thinking approach. The study by Othman and Rahman (2011) suggests that cooperation between teachers and students is essential for the successful infusion of creative and critical thinking skills in teaching and learning. Additionally, the infusion of these skills can influence students' learning styles and allow teachers to vary their teaching styles. Mahanal et al (2019) further support the significance of prior knowledge, stating that students with high academic ability are more likely to excel in solving complex problems that require higher-order thinking. Prior knowledge helps students access, organize, and create connections between information, as well as identify relevant and accurate information.

To further improve the integration of critical thinking in engineering subject lessons, teachers must employ several activities and approaches that induce the process. Activities such as arguments and investigations were suggested by the respondents as it helps to provide the students with the platform to exhibit the abilities of critical thinking. Applying methods such as asking critical questions, or using thinking strategies and tools helps in making the lessons better. This is also to ensure that students are guided at the beginning of the lessons in applying critical thinking. The respondents also agreed that it should be learner-centered as students are required to explore and investigate the lessons to solve the given problem. Goodson and Rohani (1998) stated that generally, students will only be given support at the early stage of their studies and are gradually trained to become more independent (scaffolding). This will train the students to think more critically and creatively. Support that is given excessively will prevent the student from developing and improving their self. According to Seibert, S. A. (2021), PBL is an ideal strategy to engage Gen Z students in higher-order critical thinking. The PBL process aligns with the definition of critical thinking and the elements of thought involved with critical thinking. For instance, in PBL, students question, analyze, synthesis, interpret, infer, reason, apply, and use intuition and creativity.

As for the abilities that students should showcase, there were 15 abilities shared by the respondents related to critical thinking. These abilities are analysis, problem-solving capability, being open-minded, interpreting, making inferences, having self-regulation, concluding, criticizing, being resourceful, managing, organising, and communicating ideas, planning, logical thinking, metacognition and evaluating. These abilities must be used in a chained process whether with all or some in the lessons to yield the final output of solving a given problem. According to Debra and Paul (2012), critical thinking is very useful during learning because students will learn to recognize, analyze, and evaluate arguments. Teaching

critical thinking has gained more importance as students need to adjust to such change by actively and skillfully conceptualizing, applying, analyzing, synthesizing and evaluating information which had been gathered from observation, experience reflection, reasoning and communication (Paul & Elder, 2004; Ruslan & Nyet, 2015).

Nevertheless, there is evidence for students to exhibit these abilities, there must be constant indirect guidance by teachers as students are still in the learning phase. Therefore teachers themselves must be equipped with the strategies to teach critical thinking skills to students. This was shared by R4 and R5 who insisted that educators must know at least certain pedagogy to induce these skills in class. To assess the student's critical thinking, observations can be made toward the student's skills when data or information is needed to compare, discriminate, organize, manage, classify and identify cause and effect (Yahya & Nooradinah, 2012).

Conclusion

The main purpose of this research is to find out how critical thinking can be integrated into engineering subjects in Malaysian technical schools as well as what constructs or abilities can be shown to exhibit critical thinking abilities among students. Based on the findings, it is found that there must be an element of settings prepared by teachers to execute critical thinking-based lessons. These settings must be backed by a pedagogical approach that induces critical thinking qualities and abilities by the students. On top of that, teachers must at least have the knowledge and understanding of what critical thinking is. There must also be certain tools or strategies employed by the teachers to induce critical thinking activities. In terms of constructs or abilities that should be demonstrated by the students, there were 15 abilities mentioned by the respondents which are

- Analysis,
- Problem-solving capability,
- Being open-minded,
- Interpreting,
- Making inferences,
- Having self-regulation,
- Capable of concluding,
- Criticize,
- Being resourceful,
- Able to manage,
- Organization, and
- Communicate ideas,
- Planning,
- Logical thinking,
- Metacognition
- Evaluating.

Following the findings of this research, it is recommended that engineering subject teachers in technical schools in Malaysia consider integrating these approaches into their lessons to enhance critical thinking capabilities among our technical school students.

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