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Article

Development of Criticality in Thought: A Conceptual Framework for Online Student Discussion Forums in Higher Education

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Abstract
Assessing student understanding and extending student learning beyond the face-to-face or synchronous online lesson is commonly done with the use of online discussion forums. However, the challenge reported by tutors of higher education has always been the lack of active participation and critical engagement by students unless the task is graded formally. Researchers have been investigating various approaches to facilitate effective learning experiences such that students are motivated to engage others when they are tasked to partake in such asynchronous discussions. This paper explores how I sought to engage my Engineering undergraduate students, reading a critical thinking and writing module taught in a blended learning environment, in online discussion forums with the adoption of the Paul-Elder critical thinking framework. The aim was to develop higher levels of criticality in thought in students' forum responses, while demonstrating the application of the critical thinking tools, such that they were able to collaboratively construct knowledge and deepen their conceptual understanding of Engineering leadership. Results of the analysis found that students were engaged in spontaneous dialogic discussions in the form of repeated extended posts published in the online discussion forums. Furthermore, analysis of student critical reflection essays also confirmed that the online discussion forums, with a deliberate use of the tools of the framework, had contributed to their development of critical thinking skills to deepen their understanding. This paper concludes with a recommendation for tutors of higher education to make the assessment of students' critical reflection or critical thinking skills visible for students with a proposed conceptual framework for online discussion forums.

Keywords
Online teaching, asynchronous discussion forums, blended learning, critical thinking, writing skills

1 Introduction

The use of an online discussion forum is rather common in higher education. Not only does it provide an avenue for fruitful discussions on the topic of learning, but it is also argued to eliminate communication barriers that may exist between students and their tutors, particularly involving introverted students who would not participate actively in face-to-face or synchronous lessons (Onyema et al., 2019). Scholars

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have posited that the use of online discussion forums is an effective tool for engaging students outside the physical classroom as it allows students to post messages to the discussion threads, interact and receive feedback from the tutor and other students, and foster deeper understanding (Balaji & Diganta, 2010). Moreover, since it is an asynchronous format, students have the additional benefit of time and space to consider their position before responding to others (Boud et al., 2001). These online discussion exchanges are seen as a cooperative process of learning (Boud et al., 2001) as student participants establish a relationship with one another through engagements with written posts.

In a successful asynchronous discussion forum, it is argued that interactions between participants mimic that of a face-to-face discussion. Both would have back-and-forth dialogue among participants, thus making it a dialogic experience for students and tutors. Moreover, the main benefit of asynchronicity is that students "do not have to be "present" at the same time to be able to participate in the discussion, thus freeing them up in terms of both space and time" (Griffin, 2019, p. 3). This means students can continue to discuss a topic for as long as there is interest and no matter how many others have already responded (Parks-Stamm et al., 2017). Researchers have also reported that in online environments, learning occurs through an egalitarian process in which participants generate, challenge, reflect upon, and defend ideas, thereby constructing meaning through these exchanges (Paul & Elder, 2012). Moreover, research has shown that asynchronous online discussion is an ideal tool for supporting collaborative knowledge construction as when students interact to share knowledge and solve problems, they would need high-level thinking (De Wever et al., 2010). Hence, online discussion forums have the potential to develop critical thinking skills among participants who collaboratively produce content through peer discussions (Lee & McLoughlin, 2007). However, research on effective online instruction which includes student deliberation in forums, concludes that in order for effective learning to take place, there must be an adoption of collaborative and discussion-oriented strategies (Dixson, 2010). Arguably, without a deliberate instructional strategy, the use of discussion forums would not lead to collaborative construction of knowledge and deepening of understanding.

Indeed, despite its well-documented merits, the use of online discussion forums has its challenges such that it warrants tutors' need to adopt instructional strategies, like posing a question for their peers' posts, for its effective use in teaching and learning. For productive online discussions, it is crucial for students to be highly motivated in the first place to participate in online discussions (Mettiäinen, & Vähämaa, 2013; Patel, 2020). Without a clear aim and learning objective shared, students may not see the value in the use of discussion forums. Just like in the use of other tools for technology-enhanced learning, online activities must be designed with relevant pedagogical knowledge to enhance students' learning experiences (Asoodar et al., 2016; Patel, 2021a; Patel, 2021b). According to Comer and Lenaghan (2012), online activities like participating in discussion forums, must be planned, and designed by tutors in such a way that timely feedback should also be provided to students so that they can utilise it as a formative assessment on their learning and consequently have their anxieties reduced. Furthermore, tutors often report that active student participation with high levels of critical engagement in their discussions can only be achieved if the task becomes a graded assessment. Indeed, scholars suggest that students would generally perceive that tutors would assess whichever learning that is of value (Burkett et al., 2004). Hence, unfortunately graded discussion forums tend to be the strongest motivator for student participation (Seo, 2007).

Other challenges exist as well. Some students, who may be ESL learners, are not competent writers, while some do not know how to engage in a discussion (even if it is online and asynchronous) or how to engage others after sharing their own responses (Hancock, 2012). Many scholars point to the lack of participation, thread extension, critical thinking, and substantive engagement with others (Baran & Correia, 2009; Bradley et al., 2008). In fact, the use of asynchronous discussion forums tends to cause a highly stressful experience for students, elevate their frustrations and anxieties, and inadvertently promote missed learning opportunities (Berge & Muilenburg, 2006; Yeh, 2010). Some may need more help with composing and structuring their written responses for discussion. To make matters worse,

tutors are unsure on how exactly to guide students such that they will be confident in using discussion forums to extend their learning beyond face-to-face or synchronous online lessons.

While debates about face-to-face and online discussions tend to position them as mutually exclusive modes of instruction, the concept of blended learning has more recently become a subject of interest to educators and higher education institutions. In addition, although the utilisation of an online discussion forum does not guarantee that learning will happen (Parks-Stamm et al., 2017), scholars assert that since quality course materials must be supplemented with student interaction, forum discussion is as important as the course content (Schaefer et al., 2018). Therefore, this study is motivated by my desire to investigate the adoption of a conceptual framework for online discussion forums in a blended module on critical thinking and writing so as to develop a high level of criticality in thought in my students' posts.

2 Developing Critical Thinking Skills in a Blended Learning Environment

In recent years, blended learning has been widely adopted across universities with some scholars referring to it as the "new normal" in course delivery (Norberg et al., 2011, p. 207). Blended learning (BL) has evolved from integrating face-to-face experiences with text-based, and web-delivered activities, like asynchronous discussion forums (Garrison & Kanuka, 2004) to a combination of online and face-to-face experiences that support each other, without the online component being exclusively text-based communication (Ginns & Ellis, 2007). Researchers have discussed innovative practices for BL that have the potential to enhance learning effectiveness. A learner-centered environment that emphasizes interactivity, BL could include instructional activities to develop problem-solving skills, critical higher-order thinking, and application of knowledge (Breivik, 2015).

Scholars posit that blended learning provides learning experiences that enable the development of critical thinking skills in students through the facilitation of technology-enhanced learning, and inter-personal interactions in face-to-face instruction (Giraldo-García et al., 2015). Researchers also argue that when compared to the purely face-to-face traditional instruction method, the blended learning model contributes more to critical thinking dispositions and levels in students (Korkmaz & Karakusm, 2009). This is because leveraging on blended learning technological tools with an integration of explicit critical thinking skills development provides an additional opportunity for motivated students to achieve higher levels of thinking and practice critical thinking skills (Carmichael & Farrell, 2012). However, tutors need to develop and design the course adopting the blended learning approach to achieve the intended critical thinking learning outcomes in students. Tutors also need to effectively facilitate students' learning processes and support social interaction among students when they are engaged in online spaces (Harahap et al., 2019).

In another study investigating how online and blended collaborative communities of inquiry can create a cognitive presence that supports higher-order learning processes and outcomes (Garrison et al., 2001), the researchers sought to determine if the two learning environments had any differing effect on the effectiveness of developing critical thinking (Akyol & Garrison, 2011). Similar to the current study, the researchers collected data from article critiques and weekly online discussions. In addition, students were also expected to apply a theoretical framework in their online discussions and assignments. The researchers found that it is crucial for tutors to facilitate critical thinking in the blended course by modelling questions (Akyol & Garrison, 2011) - categorized as procedural (those with a right or wrong answer), preference (those with no correct answer), and judgment (questions requiring critical reflection to obtain the best answer (Paul & Elder, 2006). This highlights the importance of the dialogic nature of interactions in the asynchronous discussion forums where a high level of criticality of thought needs to be facilitated. However, notwithstanding the strengths of asynchronous online discussion forums to support higher levels of thinking through sustained discourse and reflection (Akyol & Garrison, 2010), assessing the quality of learning outcomes in such online learning spaces has still been an ongoing challenge.

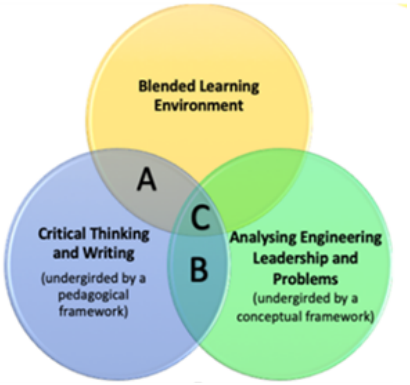
As part of a blended learning model, tutors typically utilise asynchronous online discussions when designing and facilitating learning and higher order thinking skills. Several models and tools have been developed to analyse online forum discussions to ensure a high level of cognitive activity is achieved or to examine the relationships between interaction and learning (Redmond & Lock, 2006). Scholars argue that there needs to be a synergistic interaction which refers to focused and coherent forms of student–student interactions to ensure the development of higher-order thinking like critical thinking, (Schrire, 2004). In fact, Schrire (2006) argue that findings of her research suggest that the "achievement of such synergistic interaction in computer conferencing will lead to deeper learning" (p. 67). While she emphasised the use of multiple instructional approaches (ie. forums, videos, e-lectures, etc.) to reflect and assess the complexity of higher order thinking and knowledge building processes in online spaces, she highlights that there have been few studies that investigate the development of higher levels of cognitive presence in blended learning environments using different sources of data (ie. instructional approaches). Therefore, this study addresses the gap in literature on how asynchronous discussion forums can effectively develop critical thinking skills in students as they engage in student-student interactions online.

3 The Module and Its Conceptual Framework

This paper is based on a module teaching critical thinking and writing for Engineering undergraduates at a Singapore university. The module has a tri-part conceptual framework: blended learning, critical thinking, and engineering leadership and complex engineering problems (See Figure 1).

Figure 1

Module Tri-part Conceptual Framework



3.1 Engineering leadership and complex engineering problems

Relevance to engineering practice is emphasized with references to grounded theories of engineering leadership (Rottman et al., 2015) and the seven missing basics of engineering education (Goldberg, 2009). The module adopts the belief that the challenges of being a global engineer have increasingly called upon engineers to think critically and communicate effectively to undertake developmental leadership. It aims to develop and reinforce students' critical thinking and writing skills through the analysis of case studies in engineering leadership, the construction of complex engineering-related problems and solutions, and the effective presentation of arguments (CELC, 2019).

3.2 Blended learning

As explained, the instructional approach used in the module is the flipped classroom model utilising

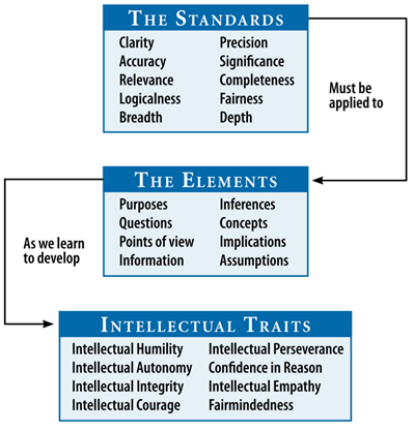
blended learning approaches. Spanning over one semester, students meet for a 2-hour face-to-face tutorial and another 2-hour asynchronous e-learning activity per week. As the module utilised the blended learning approach over the semester, students were engaged online in e-learning activities which forms as preparation for the highly student-centred and interactive whole-class and small group discussions during face-to-face lessons. E-learning activities are mainly in the form of reading of articles and engaging peers in online discussion forums or producing a write-up. While students may decide to use other online tools to manage their collaborative work, they were primarily engaged in deliberative work in online discussion forums. Thus, engaging students online in these forums, summarising their discussions and linking the pertinent discussion points and interesting insights they had collaboratively raised to the discussions the class had in face-to-face tutorials were important to ensure learning objectives were met.

3.3 Critical thinking

While there are efforts to ensure critical thinking skills in the disciplines are taught in undergraduate courses (like my writing course), they may not be done in such a way that is explicit and "visible" for students – what critical thinking skills exactly are students learning and getting assessed on. In fact, one crucial study showed a disconnect between the amount of critical thinking experience faculty believed they were providing to students and the amount of critical thinking experience students perceived they were receiving (Cooney et al., 2008). Therefore, to develop students' critical thinking skills and model them explicitly in my instruction, I adopted the Paul-Elder critical thinking framework (Paul & Elder, 2019). Richard Paul exemplified a philosophical approach to defining critical thinking - "a disciplined, self-directed thinking that exemplifies the perfections of thinking appropriate to a particular mode or domain of thought" (Paul, 1992, p. 9). This approach focuses on the hypothetical critical thinker, enumerating the qualities and characteristics and not the behaviours or actions (Thayer-Bacon, 2000). Paul (1992) points out that critical thinking skills can be taught by integrating critical thinking instruction into discipline-specific courses. Moreover, scholars have long posited that discussion and dialogues are considered central to the teaching of critical thinking (Commeyras, 1993) – a method supported by a Vygotskian perspective emphasising that thought and reasoning are required in social and instructive interactions (Şeker & Kömür, 2008). In addition, since with the Paul-Elder critical thinking, I am able to guide my students to "move from the unclear to the clear, unreasoned to the reasoned, implicit to explicit, unexamined to the examined, inconsistent to the consistent, and from the unarticulated to the articulated" (Şeker & Kömür, 2008, p. 393), the adoption of the Paul-Elder framework is an appropriate one for the critical thinking and writing module for engineering students. With such an explicit integration of a critical thinking framework, students would have an opportunity to develop higher levels of criticality in thought as they co-construct knowledge and deepen their understanding (Vandenburg, 2006).

Figure 2

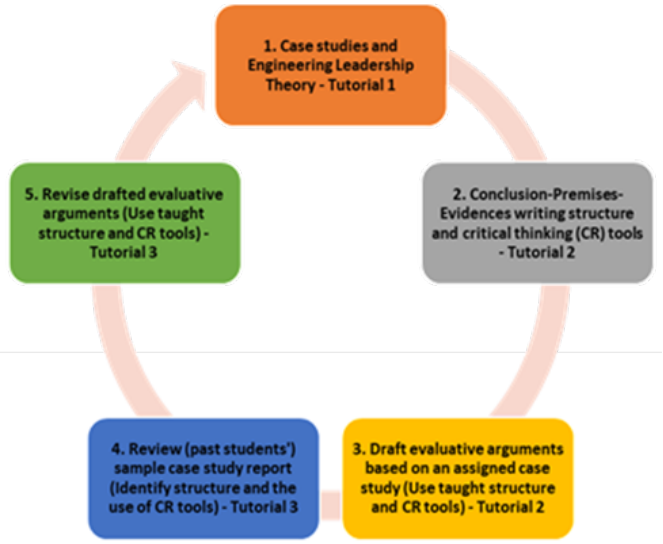
Paul-Elder Critical Thinking Framework (Paul & Elder, 2019)



The framework consists of three components – two of which are applied in my instruction: Elements of Thought and Intellectual Standards. (See Figure 2). There are ten criteria: clarity, precision, accuracy, relevance, consistency, logicalness, depth, breadth, significance, and fairness. These criteria, referred to as the intellectual standards, are used to assess the level of critical thinking in reasoning (Paul & Elder, 2006). The standards are applied to types of reasoning, called the elements of thought: purposes, inferences, questions, concepts, points of view, implications, information, and assumptions (Paul & Elder, 2006). To ensure that the teaching of critical thinking and its development (as evidenced in my students' work) is made visible, the adoption of the Paul-Elder framework is done explicitly with the use of the intellectual standards and elements of thought throughout my instruction.

Figure 3

Lesson Sequence to Write Evaluative Arguments on Engineer Leader Case Studies



3.4 The module curriculum

At the start of the semester, students were exposed to case studies about different Engineer Leaders in the Engineering industry in Singapore. I scaffolded their critical reading practices and introduced the use of critical thinking tools of analysing arguments with the relevance-sufficiency-truth model. I also modelled the use of the Paul-Elder critical thinking framework (Paul & Elder, 2019) for students to specifically identify various Elements of Thought present in the case studies. These were then assessed using the Intellectual Standards before students were taught to write evaluative arguments on the effectiveness of the Engineering leadership case studies they were analysing – applying the Rottman et al.'s (2015) Engineering Leadership model. Students also engaged in process writing with frequent peer feedback and group discussions on sample student evaluative arguments to collaboratively identify the problem(s)-action(s)-evaluation arguments. They continue to revise their own evaluative arguments until a final individual critical reflection essay was submitted for my review. Figure 3 shows the lesson sequence at the start of the semester when critical thinking and writing learning objectives were focused on.

3.5 Motivations for inquiry

Over the course of a semester, while I was the module co-coordinator, tutors had shared with me that they found students' responses online in the discussion forums to be lack-lustre in performance. They referred to students' short and superficial discussions in response to the prompts given. As students

were also tasked to respond to at least one other post, many resorted to simply agreeing or disagreeing with their peers and repeated the arguments that their peers had made by paraphrasing them in their own words. This essentially did not do much in developing student criticality in thought. They were not deepening their understanding, nor were they constructing knowledge collaboratively about the concepts of Engineering leadership from their critical analysis of the case studies. This prompted me to conduct an investigation into developing student criticality in thought in the blended learning environment of the module. Particularly, I was interested in the explicit use of critical thinking tools (based on the Paul-Elder framework) in asynchronous online discussion forums. Hence, I sought to answer the following research question: How can student criticality in thought be developed in asynchronous online discussion forums such that they are able to co-construct knowledge and deepen understanding?

4 Methodology and Analysis of Student Work

4.1 Participants

During one academic year (2019-2020), a total of 54 engineering undergraduates from three sectional groups that I taught participated in the study. In the first semester, 18 students read the compulsory module, while the remaining 36 students did so in the second semester. Students ranged in age from 19 to 24 years-old and were full-time matriculated students in Years one to four. However, a huge proportion of the students were from Year two of their studies. There were approximately three times as many male as there were female students. This action research study is an extension of a larger scale study that involved the entire cohort of about 300 engineering undergraduates who read the module in academic year 2019-2020. Results from the larger scale study are discussed in manuscripts currently in preparation. The Learning and Analytics Committee on Ethics (LACE) in the university has reviewed and approved the ethical aspects of the research based on the declaration and application submitted in August 2019. The approval reference code was L2019-07-02. Written informed consent was obtained from all student participants of the study.

4.2 Procedure

To model how I critically engage with case studies and student responses in asynchronous online discussions, I demonstrated an explicit application of the Paul-Elder critical thinking framework to guide my thinking and shape my responses. I scaffolded the level of criticality in thought I was helping my students develop by modelling exactly how I would identify Elements of Thought like “points of view”, “implications”, “assumptions”, and “inferences” from the cases of engineering leadership we were critically analysing. For responding to other posts in discussion forums, I encouraged students to apply the Intellectual Standards like “clarity”, “significance”, “breadth” and “depth” onto their peers’ forum posts, instead of merely replying if they had agreed or disagreed and paraphrasing what their peers had written. Increasingly as students successfully demonstrated higher levels of criticality in thought in their online posts, I would highlight them (with my annotations of the specific standards and elements of reasoning) in class as good exemplars. In this way, students were able to learn from one another as they saw the application of the Paul-Elder critical thinking framework in their peers’ posts.

4.3 Data collection and analysis

There are many analysis methods that have been used to assess learning in online discussion forums, but few have been applied extensively (Rodriguez, 2014). Scholars have long argued against the predominantly quantitative methods, like frequency counts, to assess the content and outcomes of

discussion forums. However, in recent years, protocols have been developed by researchers such that meaningful qualitative analysis of online discussion forums can be conducted (Marra et al., 2004). The content analysis which I adopted to assess the content of my student-student interactions in the discussion forums was the Interaction Analysis Model (IAM) (Gunawardena et al., 1997; Lucas et al., 2014). It was based on a constructivist paradigm, designed to detect evidence of knowledge construction (Marra et al., 2004). The IAM was also developed to further understand and describe the processes of negotiating meaning and knowledge co-construction in a collaborative online discussion environment (Gunawardena et al., 1997; Lucas et al., 2014). Figure 4 shows a table of the five phases in the protocol that indicates the degree of knowledge-construction activities across a distribution.

Table 1

Interaction Analysis Model (IAM) Phase Definitions (Gunawardena et al., 1997)

Phase 1 - Sharing and comparing of information	Statement of observation or opinion; statement of agreement between participants.
Phase 2 - Discovery and exploration of dissonance or inconsistency among participants	Identifying areas of disagreement; asking and answering questions to clarify disagreement.
Phase 3 - Negotiation of meaning or knowledge co-construction	Negotiating meaning of terms and negotiation of the relative weight to be used for various arguments.
Phase 4 - Testing and modification	Testing the proposed new knowledge against existing cognitive schema, personal experience, or other sources.
Phase 5 - Phrasing of agreement and applications of newly constructed meaning	Summarizing agreement and metacognitive statements that show new knowledge construction.

All student posts and student-student responses to discussion forum prompts (based on the tasks of analysing Engineer leader case studies) were downloaded from the module page in the university's learning management system to capture all student-student interactions. In addition, student critical reflections at the end of the module were also analysed. This was done to corroborate findings from the two data sources. Data analysis was done separately but merged afterward. In interpreting the overall merged results, I looked for any (converging or diverging) relationship the separate data analyses revealed. This was done using side-by-side comparison that allowed me to see how the findings of one data set confirmed or refuted findings of the other data set.

Using the software NVivo, these interactions were then coded using the IAM 5-phase protocol and further coded with all the categories of Elements of Thought (EOT) and Intellectual Standards (IS) from Paul-Elder critical thinking framework. I used the following keywords as the first level nodes: clarity, precision, accuracy, relevance, consistency, logicalness, depth, breadth, significance, and fairness, purposes, inferences, questions, concepts, points of view, implications, information, and assumptions. These were chosen as they are the intellectual standards and elements of thought from the Paul-Elder critical thinking framework - Refer to Figure 2. After this, I used the following as the second level nodes: (1) sharing and comparing information; (2) discovery and exploration of dissonance; (3) negotiating meaning and co-constructing knowledge; (4) testing knowledge with existing schema; (5) applying newly constructed knowledge. These keywords (bolded) were chosen as they are linked to each of the 5-phase protocol in IAM - Refer to Table 1.

The coding results were presented with the number of references for the node and the percentage coverage (of text). In addition, specific text search was done to create NVivo word tree diagrams to see the context of the interaction in which the text appears. This analysis allowed me to highlight the patterns of explicit use of the critical thinking tools taught in students' interactions such that they met the

stages of the IAM. Thus, statements in the interactions were double coded. From the coding, it is found that the highest coverage of references for the first level nodes are: inferences, concepts, points of view, relevance, depth, breadth, and significance. In addition, the second level nodes found to be double coded with the first level nodes are: negotiating meaning and co-constructing knowledge; testing knowledge with existing schema; and applying newly constructed knowledge. The analysis revealed that students were able to competently apply the use of the Paul-Elder critical thinking framework to deepen their understanding and collaboratively discover new interpretations from their joint analysis of Engineer leader case studies.

5 Development of Criticality through Co-construction of Knowledge in Discussion Forums

In this section, I will show how the IAM content analysis on the student-student interactions in the discussion forums revealed how students applied the critical thinking tools, based on the Paul-Elder framework, in a way that enabled them to co-construct knowledge and deepen understanding.

In sample 1 (see transcript below), Student A responded to the prompt for analysing an Engineer leader case study and evaluating the engineering leadership actions presented. There was evidence of specific EOTs like identifying assumption, perspective and interpretation when elaborating on the student's line of reasoning as he/she engaged with the evaluative arguments shared in the post. In addition, the student was also able to demonstrate Phase IV of the IAM when he/she tested proposed new knowledge and linked it to an existing schema. Arguably, the student would not have been able to extend his/her critical thinking if he/she had only provided descriptive "recall" details of the Engineering actions presented in the case study (denoted with underlined text in the sample). The post shared in the discussion forum would also be shorter with no opportunity for others to respond to, not achieving other phases of the IAM. Hence, there would be negligible co-construction of knowledge and deepening of understanding.

Sample 1 (Student A)

Date: 05-Sep 11:31 PM

"…. He highlighted that most engineers who assumed management role are proficient in solving technical problems but not unexpected and irrelevant emergency such as a siren going off **(Details from the CASE)**. Usually, they will get flustered by unexpected events and lacked the ability to apply problem solving skills to problems outside of their technical expertise **(IAM Phase IV: Linking to Existing Schema)** and thus, the first thing that came to their minds were to inform their superiors **(EOT: Assumption/Perspective)**. However, that was not the case for him, he was able to... This is in line with the Rottman model's technical mastery that an engineer like Mr Loke not only able to solve engineering problems but also problems outside of his expertise **(CLAIM)**. Collaborative optimization was demonstrated by Mr Loke's as he understands the importance of working as a team to deliver the results way back in his schooling days when he joined team sports and also while he was working in the company **(CLAIM – IAM Phase IV: Testing Proposed New Knowledge)**. Organizational innovation was also visible during his stay in TMT. He came up with a 2x2 matrix for telco that aimed to achieve both high broadband and high mobility quadrant, which is what we commonly as 4G network nowadays. He came up with this in the 1997 when no other engineers could. The thing that inspired him in this innovation was the fact he knows that engineering works is not how good the thing is but what the customers want **(EOT: Interpretation/Inference)**…."

*underlined text: descriptive "recall" details of the Engineering actions presented in the case study

***bolded text: application of the Paul-Elder framework and phases of the IAM**

In Samples 2 and 3, two separate students had responded to their peers' posts. Interestingly, Student B and C had not been too quick to simply agree with their peers' responses and arguments. For example, Student B argued that the Engineering leadership case study analysed could be categorised under the orientation Innovation (Rottman et al., 2015) instead. This shows evidence of the IAM Phase II which is an exploration of dissonance where students are able to identify areas of disagreement in their discussion. The student further elaborated with a supporting premise to justify his/her argument. After this, the student went on to provide an analogy as an example to further illustrate his/her counter evaluative argument. There is also evidence of the EOT interpretation when the student explained how the analogy supported his evaluative argument. This provided the rest of the students in this discussion forum with additional insights that could deepen their understanding of the Engineering Leadership framework applied in the analysis. The co-construction of knowledge here is also evidence of IAM Phase IV when the student was able to propose new knowledge – the argument that orientations *Technical Expertise and Innovation* could be complimentary. The student was also able to extend his argument with further explanation with the application of EOT Implication/Consequence and IS Breadth by posing questions on the Engineer leader's ability to solve the complex problem had he made a different decision. This was also the case in Student C's response when he/she posed questions when providing a counter argument.

Sample 2 (Student B)

Date: 05-Sep 11:55 PM

Hi Student A **(Responding to another)**, while you put this under technical expertise, I would put it all under innovation as I felt that it was a calculated risk that Mr Loke took **(IAM Phase II: Exploration of Dissonance – Identifying Areas of Disagreement)**. I guess technical expertise works too as it is a creative and detailed analysis of the technical problem. Mr Loke was heavily inspired by his professor's take on problem solving, to start with the end in mind. By starting with the end in mind, it helps make the plan clearer as we can more easily see the path by backtracking.

An apt example would be solving mazes. **(IAM Phase IV: Testing Proposed New Knowledge)** Any maze would be much easier to solve when starting from the end as opposed to starting from the initial point. From the initial point, it is more likely to run into dead ends and render much of your route entirely useless. By backtracking from the end, you 'start' from the correct path and a good start is half the battle won. Creative analysis of problems is an important skill to have **(EOT: Interpretation)**

Also I too would like to think that Rottmann's model is heavily intertwined. Technical expertise and Innovation goes hand in hand **(IAM Phase IV: Testing Proposed New Knowledge)**. They complement each other and a good Engineer Leader should ideally have both. Imagine this - had Mr Loke thought about the problem creatively but lacked the ability to take the calculated risk, do you think he would have made the correct leadership decision that night? Or if he decided to take the risk to start from the system level test without analysing the problem first, do you think he would succeed in solving the problem? **(CLAIM; IAM Phase III: Negotiation of co-constructed knowledge) (Intellectual Standards: Breadth – Looking at it in other ways. EOT: Orientation, Implications and consequences)**

*underlined text: descriptive "recall" details of the Engineering action presented in the case study

***bolded text: application of the Paul-Elder framework and phases of the IAM**

Sample 3 (Student C)

Date : 05-Sep 03:01 AM

"Hi Student X, your analysis of Mr. Loke's lecture keeping in mind Rottmann et al. is quite interesting. You have used the analogy of Texas Hold'Em poker that he had given to show that

he is a calculated risk taker. He has advised many companies to shut down or 'fold' before causing any more damage as in his words, "A bad decision can make you bankrupt." But what about the time when he worked as a senior engineer in a factory and his product did not reach the six-sigma standard? **(IAM Phase II: Exploration of Dissonance – Identifying Areas of Disagreement)** Which orientation do you think he's leaning towards in this scenario? **(Intellectual Standards: Precision, more details OR EOT: Information (facts/observations)**

(Details from the CASE) He had made the call of shutting down and disrupting the entire system which had probably cost the company tens of thousands of dollars. The thinking behind this was that if he had let the system run its course, then that particular batch would probably develop defects and would have to be recalled. This could have caused the company worse losses and also would have ruined its reputation and credibility in the market. **(CLAIM; IAM Phase IV: Linking to Existing Schema)** This strengthens the point that good decision making skills are required to be a successful engineering leader ….." **(CLAIM; IAM Phase III: Negotiation of co-constructed knowledge)**

*underlined text: descriptive "recall" details of the Engineering actions presented in the case study

***bolded text: application of the Paul-Elder framework and phases of the IAM**

In Sample 4, there is further evidence that a student was able to extend his/her evaluative argument with elaborations that applied the EOTs interpretation, Implication and Concepts. This allowed the student to provide new insights into his/her evaluative arguments about the effectiveness of the Engineer leader's actions, while linking them to the adopted conceptual framework of Engineering Leadership (Rottman et al., 2015). As a result, there is evidence of a deepening of student understanding and co-construction of new knowledge in the discussion amongst students. Student E was able to provide other sources of evidence (additional credible references) to support the claims he/she was making in the forum post. Together with the elaborations provided, the extended discussion response is found to have complimented the IAM Phases of Testing new knowledge and Application of Newly Constructed Meaning. It is evident in Sample 4 that the details from the case study the student was analysing was kept at a minimum (denoted with the underlined text in the Sample). This solidifies my argument that without the application of the Paul-Elder critical thinking framework, students might not know how to demonstrate criticality in their responses on discussion forums. Their responses might also be superficial in that they would not be as lengthy and insightful as the ones shown in these Samples. Hence, we see clear evidence of a deepening of student understanding of the concepts of Engineering leadership and co-construction of new knowledge with an explicit adoption of the Paul-Elder framework to guide student engagement in discussion forums.

Sample 4 (Student D)

Date : 05-Sep 02:44 AM

"… He mentioned an instance when he hired someone and then in turn, that person hired two of his mentees. This lead to their work being completed in two months' time instead of eight **(Details from the CASE)**. This shows that Mr. Loke has an eye for individuals' strengths and weaknesses and he knows how to plan and delegate work in such a way that every individual in the team is working at maximum efficiency **(CLAIM, EOT: Interpretation/Inference; IAM Phase 1: Sharing of Information)**. He brings out the best in every team member. He is also a great decision maker as seen by another instance…. The wisdom in his decision comes from the fact that if the product did not meet the set standard, there was a possibility of recall of that particular batch in the future, which could have caused the company more damage **(EOT: Implication/Consequence)**. This illustrates his 'collaborative optimization' attributes **(CLAIM)**.

I also found his PACKING model very interesting. It stands out from the model as proposed by Rottman, Sacks and Reeves [1] and by the Huffington Post [2] as he proposes traits that

a leader should possess, while the two propose how a leader should act. I feel that the model proposed by the Huffington Post is mainly inclined towards the 'organizational innovation' kind of leadership and that it is quite generic **(IAM Phase IV: Testing new knowledge using other sources)**. Using the critical analysis of Schell et al. [3] **(Using evidences or references to seek clarity and show relevance, EOT: concepts)** of the current engineering literature and keeping Rottman et al [1] in mind, we can understand that there are many different kinds of approaches and models to leadership in engineering, and Mr. Loke's was just one of them which was clearly defined and influenced by the path he took. I believe that each one of us will learn from our experiences and become able leaders in our different but effective ways…." **(IAM Phase V: Application of Newly Constructed Meaning)**

*underlined text: descriptive "recall" details of the Engineering actions presented in the case study

***bolded text: application of the Paul-Elder framework and phases of the IAM**

Students' critical reflection essays at the end of the module also confirmed that the online discussion forums, with a deliberate use of the tools of the Paul-Elder critical thinking framework, had contributed to their development of criticality in thought. Furthermore, they were confident that the development of their critical thinking and writing skills had enhanced their understanding of Engineering leadership and solving complex Engineering problems (Refer to sample quotes below).

Student A wrote:

The weekly forums had provided me with ***a platform to improve the (critical thinking and writing) skills*** *as I have to critically analyse the article/question posted and I have to provide my feedback on another person's (post). Through this exchange, I am exposed to* ***numerous insights and perspectives*** *from my module mates… and for me to* ***exercise my critical thinking and writing skill*** *in this module. Looking back at my first forum post, I believe I have improved my critical thinking and writing skill. This skill that I have acquired has* ***increased my competency in presenting my arguments effectively.***

Student B wrote:

The most important takeaway I had would be the ***art of thinking and analysing problems in a 'critical' way***, which is ***objective and systematic***. The ***online forum activities*** which involved engineering case studies, such as the one on technological inventions for real world problems, allowed me to ***gather information and evaluate them effectively to provide my opinion backed up with substantial evidence***. I am able to make a ***reasoned judgement and draw conclusions*** from the given information, hence demonstrating critical thinking.

Student C wrote:

The most significant impact of this module on ***the way I think and write*** would be the technique of ***asking critical questions***. I learnt how to ask good questions, in aspects such as ***breadth, significance, relevance*** and many more. This is especially useful as an initial step for me to ask myself critical questions about a problem before proceeding to write ***so that I am aware of what I want to address***, and I can evaluate the given information effectively. Also, this guide helps me to ***ask critical questions when peer reviewing in forums***, other groups' assignments, and during oral defence of the presentation, where they ***help to trigger the thinking of the writer to improve their work or be open to new ideas***.

Student D wrote:

Through this course, my team ***addressed our weakness in the preliminary submission by using the suggested concepts tools by Paul and Elder*** – namely the standards and elements of thoughts. The feedback received ***taught me the steps and tools*** to lead to more ***conscious and therefore effective problem-solving through critical thinking***. The suggestions for strengthening the preliminary submission are analysed using the Paul-Elder tools. With a ***better***

understanding of the nature of the comments or question, it helps us to identify the issue we are facing.

Besides using the standards to help us in analysing the comments, we had used the elements of thought to further improve our work. The ***elements of thought help us to critically analyse our work and the assumption that we have made*** in our first submission. This helps us to ***identify the missing points*** in our work. Thus, we improve our second submission by ***adding more relevant evidence*** such as scholarly articles to ***strengthen our reasoning***.

6 Discussion and Recommendation

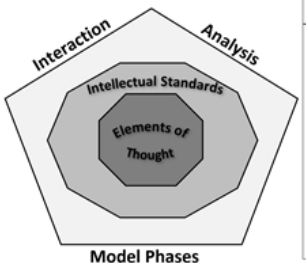
The above analysis emphasizes the impact of the use of the Paul-Elder critical thinking framework to develop critical thinking and writing skills for students in the module to internalize concepts of engineering leadership. With the Elements of Thought from the framework identified in each other's forum posts, students were able to offer deeper insights into their analysis of the Engineering leadership cases. In addition, the use of Intellectual Standards from the framework also allowed students to assess their own, and their peers', thinking so that they could co-construct new interpretations and knowledge collaboratively. The findings also show that without the extended (in terms of length and criticality) forum posts (Bradley et al., 2008) with elaborations using the Paul-Elder framework, students would only offer descriptive "recall" details from the case studies. Such demonstration of superficial thinking in discussion forums, which lacks criticality, and the lack of substantive engagement with others (Baran & Correia, 2019) was a problem many tutors reported initially.

A further content analysis of the student-student interactions in the discussion forums with the Interaction Analysis Model (IAM) revealed that students were able to demonstrate all five phases of the IAM. For a start, they were able to share information and opinions easily (Phase 1), and then use the tools of the Paul-Elder framework to highlight and explore any dissonance or areas of disagreement among themselves (Phase 2). This was also done with the posing of critical questions using the Intellectual Standards to clarify disagreements or differences in opinions. Next, students were able to negotiate meaning and co-construct new understanding or knowledge which were based on their discussions (Phase 3). This was typically supported with the sharing of existing schema, personal experiences or other sources (Phase 4). Finally, students were able to phrase their agreement and apply the newly constructed interpretations in evaluative arguments acceptable by all (Phase 5). Hence, the explicit use of the Paul-Elder framework in guiding students' forum posts showed that high quality discussions can take place where students generate, challenge, reflect upon, and defend ideas, thereby co-constructing meaning (Paul & Elder, 2012). If tutors were to make the critical thinking tools visible for students, online discussion forums have the potential indeed to develop critical thinking skills among students who collaboratively produce content through peer discussions (Lee & McLoughlin, 2007).

It is apparent from the findings of this study that any general guidelines, like posting once and responding to another or posing a question for another, would result only in unproductive and ineffective discussion forums (Farmer, 2004). Moreover, simply making discussion forums graded or part of the participation mark for the module is not going to help students develop critical thinking skills (Sheard et al., 2003). Besides, even if discussion forums were made compulsory and that student participation would award them marks, tutors do not look forward to the highly subjective and at times "random" assessment of using quantity (number of posts or length of posts) to assess students (Dooley & Wickersham, 2007). Hence, I would propose an explicit use of a conceptual framework that tutors can adopt to not only guide their students on how to develop critical thinking skills but demonstrate criticality in their discussions such that even the assessment of the task of engaging one another in discussion forums become clearly visible to both tutors and students.

Figure 4

Proposed Conceptual Framework to Guide Students' Use of Critical Thinking in Discussion Forums (adapted from Gunawardena et al., 1997; Lucas et al., 2014 & Paul & Elder, 2019)



Step 1: Identify Elements of Thought (EOTs)	Step 2: Apply Intellectual Standards onto the EOTs	Step 3: Aim to Achieve one of the IAM Phases
Purpose Questions Points of View Information Inferences Concepts Implications Assumptions	Clarity Accuracy Relevance Logicalness Breadth Precision Significance Completeness Fairness Depth	Phase 1 - Sharing and comparing of information Phase 2 - Discovery and exploration of dissonance or inconsistency among participants Phase 3 - Negotiation of meaning or knowledge co-construction Phase 4 - Testing and modification Phase 5 - Phrasing of agreement and applications of newly constructed meaning

The proposed conceptual framework is directly inspired by the tools in Paul-Elder critical thinking framework (Paul & Elder, 2019); namely the Elements of Thought and the Intellectual Standards, and the Interaction Analysis Model Phases (Gunawardena et al., 1997; Lucas et al., 2014). (See Figure 4) The first step is to encourage students to think through their reasoning, either of their own or their peers, in terms of the 8 Elements of Thought (EOTs). Then, they are to apply any of the Intellectual Standards to assess the EOTs. Finally, as students seek to elaborate on their arguments, they are encouraged to aim for any of the phases of the IAM when offering insights into their evaluations. Tutors can share this 3-step framework with students when they are modelling its application in their own responses to students' posts or whole-class discussions in face-to-face lessons. Tutors can also annotate students' discussion posts or responses (during face-to-face lessons) in the module to show when they have used the tools of the framework. By doing these, tutors are explicitly modelling the application of the framework and making the steps of the framework visible to students.

Although researchers have presented instructional strategies for tutors to motivate students to actively participate in discussion forums, such as developing a template for automatically classifying topics (Wise et al., 2016), buy-in from tutors have been low. Gaspar et al. (2010) also propose instruments to assist tutors to classify questions posted by students on forums in order to obtain quantitative measures and to understand the types of participation. These have not been particularly helpful for tutors due to the perceived overload of work in monitoring level of student participation. Besides, these strategies do not resolve the issue of the lack of criticality, deepening of understanding and co-construction of knowledge among students. Furthermore, without a meaningful conceptual framework, inexperienced tutors would feel lost when they are required to provide students with timely feedback. When such low levels of cognitive engagement occur in discussion forums, students may feel isolated (Abawajy & Kim 2011). Consequently, this results in limited student participation and lack of criticality in the discussion (Watson, 2008).

In terms of using an analytical tool, I have found that the Interaction Analysis Model (IAM), which Lucas et al. (2014) further developed, served as an excellent content analysis protocol to adopt when tutors are keen to investigate the learning that goes on in discussion forums. Marra et al. (2004) argued that practitioners and researchers must use analysis protocols which are contextualised within the larger culture of research participants if an understanding of how the (online) discourse represents the understanding being built collaboratively. Hence, the IAM is also a suitable protocol when the context of the online discussion forum is a crucial factor to consider when tutors are analysing knowledge creation and meaning making experiences of their students.

7 Conclusion

The use of discussion forums to assess student understanding and extend learning beyond the face-to-

face or synchronous lessons have been prevalent in higher education. As pointed out by scholars, with collaborative discussion forum tasks designed for interactivity, students would have the time and space to think and engage each other with deliberate thought. Moreover, with discussion forums, students would have the benefit of time to think about the prompts, read responses from their peers critically, scrutinize the information and insights shared, and evaluate differing perspectives before responding to peers (Paul & Elder, 2012). This paper acknowledged the importance of interactivity in online discussion forums such that with active participation, higher engagement and explicit application of critical thinking tools, discussion forums can be meaningful alternatives to the interactive face-to-face or synchronous discussions. However, a review of past studies found few that focus on how the quality of interaction in discussion forums particularly in developing critical thinking skills and how they can be explicitly taught. Therefore, as I sought to engage my Engineering students to collaboratively co-construct knowledge, deepen their conceptual understanding of Engineering leadership while demonstrating the application of the critical thinking framework in online discussion forums, a conceptual framework is proposed as a way forward in looking at the assessment of student's critical reflection and making the demonstration of critical thinking skills visible for students and tutors.

In times of online learning and blended learning approaches in higher education, Chan and Wilson (2020) reflected on how best to adapt face-to-face teaching materials for the online environment. While they shared that tutors could afford to use technology, even if it is merely to substitute and augment an offline task, it cannot be treated as context-free. Effective teaching still requires an understanding of how technology relates to pedagogy and content. Reflections in this paper also lead me to the all too familiar 'potential-practice gap', which potentially poses a challenge to the further emancipation of technologies as a viable option for, in my context, the learning and teaching of critical thinking and writing. Thus, I have always fallen back on Koehler and Mishra's (2006) Technological Pedagogical Content Knowledge (TPACK) framework. It serves the foundations for argument on the need for pedagogically informed ways of learning and teaching with technologies. Central to understanding the TPACK framework is the capacity to separate the three components (i.e., content, pedagogy, and technology) while also understanding that they co-exist in a dynamic transactional relationship (Mishra & Koehler, 2006). True technology integration is understanding and negotiating the relationships between these three components of knowledge. Such an understanding provides a foundation for new pedagogical outcomes that enable educators to effectively teach, especially in the unprecedented times of emergency remote teaching.

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