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Critical Thinking and Socratic Questioning in Asynchronous Mathematics Discussion Forums

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Abstract
The study was an attempt to measure critical thinking in two asynchronous discussion forums in an engineering mathematics unit. The Socratic questioning technique was the moderation strategy employed in the forums. The participants of the study were 60 undergraduates from Swinburne University of Technology, Sarawak Campus, enrolled in a mathematics course. Quantitative and qualitative data were collected. The findings of the study showed that the Socractic questioning technique encouraged critical thinking among the participant students. Although the level of critical thinking exhibited was in the lower levels, the critical thinking scores improved from the first forum to the second forum. The perceptions of the participants indicated that the online discussion forums were helpful in promoting critical thinking and that the thinking skills progressed from the first to the second forum.

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Introduction
Mathematics is about problem solving, reasoning and communicating that empowers us to confidently explore, conjecture and reason logically about the world around us (National Council of Teachers of Mathematics (NCTM), 2000). The goal of mathematics teaching is developing the ability to solve complex mathematics problems and mathematics instruction should emphasize the process rather than the product (Kosiak, 2004). Communication is an important process in learning mathematics allowing for sharing of ideas and clarifying of understanding. There is a need for communities of mathematical inquiry, where students learn to speak and act mathematically through participating in mathematical discussions and solving new or unfamiliar problems (Harskamp & Suhre, 2007). The ability to think critically is a necessity to thrive in a globally competitive society (Sendag & Odabasi, 2009). Quitadamo and Kurtz (2007) calls for institutions of higher learning to produce graduates, who can think critically, communicate effectively and have lifelong learning skills. Mathematics and critical thinking cannot be separated for meaningful learning of mathematics (Innabi & Sheikh, 2006).

Online learning provides an opportunity for a shift from the lecture model to the community model of instruction. Computer-supported systems categorized according to the time matrix of synchronous (same time) vs. asynchronous (different times) (De Leng et al, 2009) enabled collaborative learning communities to assist students pose and explore conjectures, understand mathematical concepts, and improve mathematical models (Nason & Woodruff, 2003). Asynchronous online course delivery with its tag line of “learn anytime anywhere” (Allen & Seaman, 2007) using media such as discussion boards, wikis and Weblogs is not just for online education. Many face-to-face courses also use these online tools as asynchronous communication promotes discursive and course-related thinking without the constraints of linearity or real-time interaction online, and provides socio-cognitive support for learning (De Leng et al, 2009; Schrire, 2006). Online learning is grounded in a collaborative constructivist view of teaching and learning which strives to create environments where learners actively participate in ways that help them to construct their own knowledge (Sendag & Odabasi, 2009). This differs from the instructivist approach where the teacher interprets the world and ensures that students understand the world as they have been told (De Smet et al, 2009). Social constructivists believe that collaborative work can help problem solving and learning performance (Liu & Tsai, 2008). Tertiary education makes use of commercial online Learning Management Systems (LMS) such as Blackboard and WebCT as avenues for asynchronous discussions also known as discussion forums (DFs). Research has shown the potential of DFs for creating and supporting a community of inquiry and mediating critical reflection and discourse (Levine, 2007). DFs can be powerful learning resources, if instructors are able to encourage thoughtful postings and students are engaged in high quality discussions (Bliggnaut & Trollip, 2003).

Scaffolding can assist students in mathematical problem solving. Scaffolding by the instructor, is a factor that can garner good participation and peer interactions in asynchronous discussions (Kienle & Ritterskamp, 2007). Socratic questioning is a scaffolding technique that can be used to guide students in generating thoughtful questions (Paul & Elder, 2006), and facilitate students' critical thinking skills (Yang et al, 2005). Yang (2008) indicated that moderators who used Socratic dialogues during small group online discussions were successful in developing students' critical thinking skills in a large university class. "The precision and thoroughness of questioning and thought is epitomised by Socrates and what has become in recent times Socratic questioning…. Socratic questions are underpinned by: logical sequencing, engagement in dialogue, and based on experience" (Davis, 2007, p.99).

In case-based learning scenarios, Lee (2004) has referred to the use of teacher-led Socratic dialogues to follow individual student's analytical thinking in a large group classroom situation. Yang and Chou (2008) have shown how teaching assistants practiced Socratic questioning prompts (Hew & Cheung, 2008), to guide students in exploring ideas or statements in depth and breadth and to cultivate strategies to foster students' CT disposition. The six categories of Socratic questioning prompts are: Questions of clarification, Questions that probe assumptions, Questions that probe reasons and evidences, Questions about viewpoints or perspectives, and Questions about the question. It has been argued that further research is required to address questions about components of successful online DFs, where facilitators organize or guide students' discussion, and to determine whether such DFs can promote the development of students' critical thinking skills (Yang, 2008). Perkins and Murphy (2006) developed a model of critical thinking that can be efficiently and easily used to derive and present individual profiles of engagement in critical thinking during online DFs and encouraged adapting the model for problem solving environments.

Purpose of the Study

However, there are not many studies related to the use of asynchronous DFs for teaching and learning tertiary mathematics. Thus, the main purpose of the study was to investigate the effects of Socratic questioning as scaffolds in guiding and promoting critical thinking. The study investigated the following two research questions: (1) What was the level and progress of critical thinking in the online DFs, as evident from the postings in the online DFs? (2) What were the participants' perceptions of the online DFs?

Research Methodology

This study examined online DFs interactions of collaborative groups during problem solving sessions in a first year university engineering mathematics unit of the Bachelor of Engineering programme offered by Swinburne University of Technology, Sarawak Campus in Malaysia. The objective of the unit was to provide students with mathematical knowledge and skills to support their concurrent and subsequent engineering studies. The unit was supported by the online Learning Management System called the Blackboard Learning System or BBLS. Participants of the study were 60 students from the 115 students registered for the mathematics unit. The selection of participants was made by voluntary consent.

The quantitative data collected were critical thinking scores calculated from the online DFs postings. The qualitative data consisted of the online DF postings. Critical thinking was defined as "the ability to use acquired knowledge in flexible and meaningful ways, through understanding the problem or issue, evaluating evidence, considering multiple perspectives, and taking a position" (Vanderstoep & Pintrich, 2003, p. 275). The DF learning model is shown in Figure 1 and was based on the following principles: (1) learning is a dialogical process in which communities of learners socially negotiate the meaning of phenomena (De Smet et al, 2009) (2) views of knowledge are constructed by, rather than transmitted to, the learner (Sendag & Odabasi, 2009); (3) ill-structured problems and Socratic questioning are stimuli (Yang & Chou, 2008) for CT ; and (4) online DF is a collaborative mind tool (Kirschener & Erkens, 2006). The model conceived an application problem as the focus of the discussion (Sendag & Odabasi, 2009).

The problem statement is mapped onto participants' prior knowledge to enable them to construct a personal interpretation of the problem. This is referred to as the problem space in Figure 1.

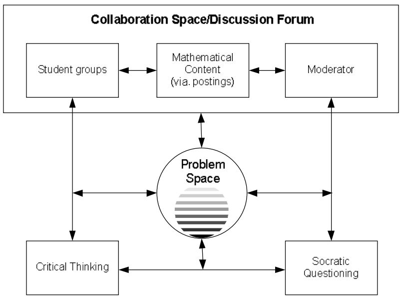
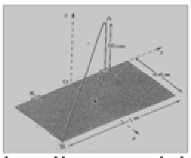


Figure 1 Model for designing online DF environment (Jacob & Sam, 2010).

The problems were engineering application problems adapted from James (2008). A sample problem and solution is shown in Figure 2. The process of solving the problem followed an iterative and cyclical process (Sendag & Odabasi, 2009). The participants were informed of the expectation to articulate goals, verify problem, relate problem goals to problem domain, clarify alternative perspectives, generate problem solutions, gather evidence to support/reject positions, construct arguments, implement and monitor solution. The occurrence of one or (preferably) many of such mental or verbal activities was referred to as critical thinking in this study. This happened within the DFs of the collaborative groups created on the BBLS.



Question: A trapdoor is raised and lowered by a rope attached to one of its corners. The rope is pulled via a pulley fixed to a point A, 50cm above the hinge as shown in the figure. If the trapdoor is uniform and of weight 20N, what is the tension required to lift the door?

Solution: $\overline{OA} = (0, 30, 50)$ $\overline{OB} = (60,-50, 0)$
$\overline{OH} = (0, 30, 0)$ $\overline{OM} = (30, 0, 0)$, M being the midpoint.
Forces acting: Tension T in the rope along BA, the weight W through M in the z-direction, and the reactions R and S at the hinges (H and K).
$\overline{AB} = (60, -80, -50)$
Hence $|\overline{AB}| = 112$. T = -T (60,-80,-50)/112
Taking moments about the hinge H, there is no moment of the reaction at H.
For the remaining forces
$MH = \overline{HM} \times W + \overline{HB} \times T + \overline{HK} \times S$
$= (30,-30, 0)\ (0,0,-20) + (60,-80,0)\ (60,-80,-50)\ (-T/112) + \overline{HK} \times S$
$= (600, 600, 0) + T\,(-35.8, -26.8, 0) + \overline{HK} \times S.$
We require the moment about the Y-axis, hence the scalar product of MH and j are taken.
$\overline{HK}$ is along j, so j. $\overline{HK} \times (S) = 0$.
Thus the j component of MH must be zero when the trapdoor just opens.
i.e. $0 = 600 - 26.8T$
$T = 22.4N$

(1) Questions that probe reasons and evidences and (2) Questions about viewpoints or perspectives

Forum: Forum 1 for Critical Thinking
Date: Thu Apr 02 2009 16:54
Author: Jacob, Seibu Mary <sjacob@swinburne.edu.my>

Subject: Summary of progress so far

1. *Student* C has calculated AP and BP- Think how could these be used to get components of T1 and T2?
2. A hint has been given to calculate CP. Think how could this be used to get components of T3?
3. How could you translate "the x and y components of the forces at P are in equilibrium" into mathematical equations?
4. Could there be a possibility of equilibrium at C? Why and what?
Seibu.

--

(3) Questions that probe assumptions
Forum: Forum 1 for Critical Thinking
Date: Thu Apr 02 2009 17:08
Author: Jacob, Seibu Mary <sjacob@swinburne.edu.my>
Subject: Re: The Question

Why only the y-components? Why not the x –components too?
Seibu.

Figure 2 A sample problem and solution and examples of moderator postings involving Socratic questioning.

Participants in each DF group generated arguments and comments, which were classified as clarification, assessment, inferences, and strategies. The lecturer moderated the DFs and scaffolded the process through Socratic questioning. Scaffolding questions serve to clarify key mathematical concepts and to advance or direct the discussions toward the solution (Chiu, 2009). The six categories of Socratic questioning prompts were questions of clarification, questions that probe assumptions, questions that probe reasons and evidences, questions about viewpoints or perspectives, questions about the question and questions that probe implications and consequences. Figure 2 illustrates the Socratic questioning in the DFs involving questions of clarification and questions that probe assumptions. Student postings gathered focus after the Socratic questioning prompts from the moderator. Sample postings are shown in Figure 3.

Forum: Forum 1 for Critical Thinking *Date: Thu Apr 02 2009 20:16* *Author: Student B* *Subject: Re: The Question* ______________________________ *Hey, how about we combine T1+T2 which is on since its on the negative side of the y-axis* *Using the vector that student A gave,* *AP = 4i + 3j + 6k* *BP = 4i - 3j + 6k* *AP+BP = (4+4)i+(3-3)j+(6+6)k = 8i+12k* *and the magnitude would be, sqrt of 8^2+12^2 = 14.4222051* *With that, we can easily get the angle and look more simpler? correct me if im wrong.*	Forum: Forum 1 for Critical Thinking Date: Thu Apr 02 2009 18:10 Author: Student A Subject: Re: The Question ______________________________ I've written down the equations for the condition where the x and y forces are in equilibrium at P. -- $\sum Fx = 0$ $-T_2 \cos 37 - T_1 \cos 37 + T_3 \cos\theta = 0$ $T_3 \cos\theta = (T_1 + T_2)\cos 37$ $\sum Fy = 0$ $-T_1 \sin 37 + T_2 \sin 37 + T_3 \sin\theta = 0$ $T_3 \sin\theta = (T_1 - T_2)\sin 37$ -- OP = 0i + 0j + 6k OC = xi + yj + 3k Therefore, CP = OP - OC I still havent figured out how to relate AP and BP to T1 and T2.

Figure 3 Sample postings which followed after the Socratic questioning prompts.

Data Analysis

The content analysis of the DF postings was done using the CAIS model. CAIS is an acronym which represented the categories (phases) of critical thinking, namely Clarification, Assessment, Inference and Strategies. The CAIS model was based on Perkins and Murphy (2006) and Paul and Elder (2006). Table 1 describes the CAIS model. After preparing the lists of categories, rules of inclusion, and examples, a research assistant was trained on the CAIS model. After the initial training, the researcher and the second coder coded 10% (47) of the postings to obtain the inter-coder agreement and Cohen's kappa (De Wever, Schellens, Valcke, & Van Keer, 2006). The computed inter-coder reliabilities were 0.89 (percent agreement) and 0.85 (Cohen's kappa) indicating appropriate level of inter-coder agreements.

Weighted critical thinking score was associated with every participant based on the classification of the postings. Different weights were associated with the different categories to distinguish between the different levels of critical thinking skills so that the score reflects the level of the critical thinking skill of the participant (Table 2). The scoring in Table 2 was developed based on the following principles: (1) the limits of the number of postings were set, assuming the average number of postings of a participant, per category, for one DF was around three, (2) higher weights were associated with the phases, inference and strategies, to indicate the higher levels of CT, and (3) the maximum weightage of one category differed by one from the minimum weightage of the next category.

Table 1 CAIS Model to Measure CT during Online DF Sessions in Mathematics

Clarification: Formulates the problem precisely and clearly.			
Analyses, negotiates or discusses the scope of the problem	Identifies one or more underlying assumptions in the parts of the problem	Identifies relationships among the different parts of the problem	Defines or criticizes the definition of relevant terms
Assessment: Raises vital questions and problems within the problem.			
Gathers and assesses relevant information.	Provides or asks for reasons that proffered evidence is valid or relevant.	Make value judgment on the assessment criteria or argument or situation.	
Inference: Reasons out based on relevant criteria and standards			
Makes appropriate deductions from discussed results.	Arrives at well thought out conclusions	Makes generalizations from relevant results.	Frames relationships among the different parts of the problem.
Strategies Thinks and suggests open mindedly within alternative systems of thought.			
Propose specific steps to lead to the solution.	Discuss possible steps.	Evaluate possible steps.	Predicts outcomes of proposed steps.

Hence, the maximum score possible was 20, if a participant had more than four postings in all categories.

Table 2 **Scoring for the critical thinking categories**

Category	No. of postings	Weightage	Category	No. of postings	Weightage
Clarification	1-2	1	Inference	1-2	5
	3-4	1.5		3-4	5.5
	>4	2		>4	6
Assessment	1-2	3	Strategies	1-2	7
	3-4	3.5		3-4	7.5
	>4	4		>4	8

This study also used a questionnaire with ten closed-ended items and two open-ended items to measure students' perceptions of the DFs. The ten closed-ended items were statements measured on a four point Likert scale ranging from Strongly Agree (4) to Strongly Disagree (1) or Excellent (4) to Poor (1). The reliability of the questionnaire was established using a sample of 30 undergraduate engineering students (Cronbach alpha = .81).

Results

The first Discussion Forum (DF1) occurred during Week 4, and the second Discussion Forum (DF2) occurred during Week 10 of the 14-week mathematics unit. Each problem solving DF sessions ran for one week. The total number of postings (including the moderator and student postings) in DF1 and DF2 were 616 and 539 respectively. The total number of posted messages, in DF1 and DF2, was calculated for each student participant. The mean total number of postings for each group was also computed. Figure 4 shows that the mean total number of postings for each group varied roughly from four to eighteen. The mean total number of postings varied from group to group from DF1 to DF2 - majority of the groups had higher mean in DF1 compared to DF2.

The categorisation of the postings was based on the four categories, clarification, assessment, inference and strategies. Clarification and assessment were taken as the lower phases of critical thinking, and inference and strategies reflected the higher phases of critical thinking. There were postings referred to as unclassified, which did not fall into any of the four categories, but were social nature.

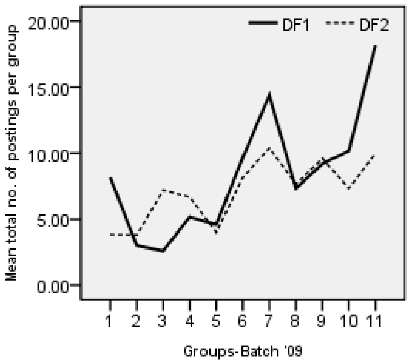


Figure 4 Mean total number of postings across the groups in DF1 and DF2.

The percentages of the student postings in the lower and higher phases of CT calculated as shown in the Table 3. The total number of classified participant postings was 423 in DF1 and 379 in DF2. However, the proportion of postings remained unchanged from DF1 to DF2. Only 19% belonged to the higher phases of critical thinking while clarification and assessment accounted for approximately 40% each in both DFs. The percentage of postings in the lower phases of critical thinking was higher compared to the higher phases of critical thinking

Table 3 Percentage of Postings (excluding moderator and unclassified postings)

Categories	DF1 (%)	DF2 (%)
Clarification	39%	41%
Assessment	42%	40%
Inference	12%	12%
Strategies	7%	7%
Total	100% (423)	100% (379)

Level of critical thinking of individuals in the online DFs

Table 4 shows the results of the analysis on individual postings. 'Unclassified' referred to those postings which did not fall into any of the four categories. The categorisation labels ended with a 1 and 2 respectively for DF1 and DF2 - for example, Clarification1 and Clarification2 referred to the category called clarification in DF1 and DF2 respectively. Critical thinking scores CT1, CT2, were calculated for each participant based on the weightage described earlier. The column headers, S.D., Q1, Q2 and Q3 stand for Standard Deviation, 25th percentile, 50th percentile (Median) and 75th percentile respectively. The means in Table 4 showed that the number of postings was more in the lower phases of critical thinking, namely clarification and assessment, than in the higher phases. But the standard deviation and the quartiles show substantial variability in the level of critical thinking.

Table 4 Descriptive Statistics of Postings based on CAIS model

Category	Mean	S.D.	Q1	Q2	Q3
Clarification1	2.77	2.580	1	2	4
Assessment1	2.93	2.622	1	2	4.75
Inference1	0.85	1.400	0	0	1
Strategies1	0.50	0.948	0	0	1
Unclassified1	1.33	1.980	0	0	2
Clarification2	2.62	1.958	1	2.5	4
Assessment2	2.50	1.827	1	3	4
Inference2	0.77	0.909	0	0.5	1
Strategies2	0.43	0.810	0	0	1
Unclassified2	0.81	1.181	0	0	1
CT1	8.33	6.045	4	7	12
CT2	8.76	5.112	4.5	9.5	14.25

Analyses of DF1 and DF2 postings revealed similar patterns in critical thinking skills. Majority of the postings fell into the lower phases of critical thinking. The combined values of the third quartile Q3 showed that one fourth of the participants posted more than 8 postings which fell into the lower phases of critical thinking. The median (Q2) also showed that half of the participants posted more than four or five postings in the lower phases of critical thinking. It was seen from the median value that half of the participants posted no postings in the higher phases of critical thinking – namely, inference and strategies, but the third quartile Q3 showed that one fourth of the participants posted more than two postings. The quartiles showed that one fourth of the participants posted more than two postings in the higher phases of critical thinking. The CAIS model scores, calculated as a weighted critical thinking score based on the CAIS model were quantitative indicators of the critical thinking skills exhibited through the online DFs. The scores between 15- 20 indicated a high number of postings in the categories of inference and strategies. Table 4 indicated that the CAIS model scores from DF1 had an inter quartile range of 8, and those from DF2 had an inter quartile range of 9.75. Thus, the quartiles showed that one fourth of the participants scored below 4 and 4.5 in DF1 and DF2 respectively. But there was a proportion of one fourth of the participants who scored above 12 and 14.25 in DF1 and DF2 respectively.

Progression of critical thinking based on the online DF postings from DF1 (Week 3) to DF2 (Week 10)

Table 5 shows that there was an improvement in the CAIS model scores, as seen from the mean scores of CT1 median scores of 8.33 for CT1 and 8.76 for CT2. The median (Q2) score for CT2 has gone up to 9.50 from 7.00 for CT1. CT1 and CT2 had comparatively large S.D. values (6.045 and 5.112) against the mean values (8.33 and 8.76) indicating although the average CAIS model scores increased, the variability of the scores also increased. These observations revealed that CT skills measured in the online DF problem solving sessions showed much variation among the participants in DF1 and DF2. But, the CAIS model scores quantitatively confirmed that CT skills have progressed from DF1 to DF2. Another observation was that CT1 and CT2 were positively correlated (Pearson moment correlation coefficient, $r = .644$, $p < 0.005$). Hence, the CAIS model scores for the participants move linearly between DF1 and DF2. As participants progressed from DF1 to DF2, the participants' critical thinking exhibited in the problem solving sessions over the DF also showed a general improvement.

Table 5 Descriptive Statistics of the CAIS Model Scores

	Batch '09 (N = 60)				
	Mean	S.D.	Q1	Q2	Q3
CT1	8.33	6.045	4.00	7.00	12.00
CT2	8.76	5.112	4.50	9.50	14.25

Participants' Perceptions of the Online DFs

The four–point scale was chosen in order to see if participants could be for or against the system of online DFs and so that the results would be conclusive. The argument was that if one is neutral about a statement, then he(she) could choose to omit the response altogether. Neutral response does not help in the analysis, hence it was avoided. Based on Table 6, the participants viewed the particular mathematics unit helped them to understand critical thinking, the group work helped in fostering critical thinking, and their critical thinking abilities became better from DF1 to DF2. Similar findings were reported in earlier sections of the paper. Majority of the participants rated themselves as average critical thinkers. The majority of the responses positively favoured the DF sessions as an excellent way to promote critical thinking. They agreed that the discussion and pace of the DF sessions became better from DF1 to DF2. The majority agreed that the moderator modelled by posing appropriate questions. Many of the participants sounded that they participated simply because of the course work marks allotted for participation in the DFs and others felt that participation was a demanding task. The rating of the DFs was also a pleasant mixture of "Excellent" (15%), "Good" (42%), and "Average" (37%). But the mean score of 2.65 (which was closer to the score of three which represented "Good") pointed to the fact that the sessions were rated good.

Table 6 Participants' Perceptions of the DFs

	Responses				Mean	SD
	SA(4)	A(3)	D(2)	SD(1)		
The HMS 111 unit helped me to understand the importance of critical thinking skills in mathematics problem solving.	14 (23%)	38 (63%)	7 (11%)	1 (1%)	3.08	0.645
Working in groups encourages/helps one to think critically.	15 (25%)	38 (63%)	7 (12%)	0 (0%)	3.13	0.596
My critical thinking skills became better from Forum 1 to Forum 2.	7 (12%)	35 (58%)	16 27%)	2 (3%)	2.78	0.691
	Excellent	Good	Fair	Poor	Mean	SD
Based on the stated definition of critical thinking, rate your current state of critical thinking.	5 (8%)	18 (30%)	35 (58%)	2 (3%)	2.43	0.698
	SA	A	D	SD	Mean	SD
The Discussion Forum problem solving sessions improved my attitude towards mathematics.	7 (12%)	32 (53%)	20 (33%)	1 (2%)	2.75	0.680
The moderator modelled the discussion by posing appropriate questions.	7 (12%)	45 (75%)	7 (12%)	1 (2%)	2.97	0.551
I participated in the Discussion Forums simply because of the marks allotted.	12 (20%)	26 (43%)	21 (35%)	1 (2%)	2.82	0.770
Moderation by the instructor (and senior student moderators) did not play an important role in the progress of the discussion.	3 (5%)	11 (18%)	34 (57%)	12 (20%)	2.08	0.766
Participation in the two Discussion Forums was a demanding task.	9 (15%)	26 (43%)	24 (40%)	1 (2%)	2.72	0.739
	Excellent	Good	Fair	Poor	Mean	SD
How do you rate the Discussion Forum problem solving sessions activated on the Black Board?	9 (15%)	25 (42%)	22 (37%)	4 (7%)	2.65	0.820

Discussions

Effective assessment of student critical thinking skills has been a major issue for higher education. Through a process of critical thinking assessment, educators can reliably assess the level of students' critical thinking (Al-Fadhli & Khalfan, 2009). Participants in this study exhibited low or moderate levels of critical thinking as evident in the postings of the online DFs. Although the majority of the participants were thinking critically to some degree, comparatively few postings were found to reflect high levels of critical thinking on a consistent basis. The proportion of high level postings stayed the same in both DF1 and DF2.

These were generally concurred with majority of studies in the literature (De Leng et al, 2009; De Smet et al, 2009; Garrison, Anderson & Archer, 2001; Hong et al, 2003; Oriogun, 2007; Schrire, 2006). Oriogun (2007) too found that the proportion of online discussion transcripts associated with higher phases of critical thinking was remarkably small. Similar results had forced Garrison et al (2001), Hong et al (2003) and Hong (2002) to question the validity of the coding system used in their study and its theoretical underpinnings. Garrison et al (2001) had also voiced similar misgiving about the coding system for analysing the computer conference transcripts. However, the researchers concluded that the system was consistent with other analysis models especially the model developed by Gunawardena et al (1997) and in fact was appropriate for adult and higher education. Based on the following arguments, the researcher also concluded that in fact the CAIS model was measuring and reflecting on the aspects of critical thinking evident in the online DF postings: (1) There was a lack of enthusiasm in posting over the online DF. This might have been due to what was suggested by Chiu (2009) for Asian students as having the fear and anxiety of independent thinking and learning, students viewing critical thinking as time consuming, cognitively challenging and exhausting. (2) Critical thinking was not observable as students might have discussed outside the online DFs, and thinking over the concepts mentally, but not sharing these thoughts with other participants. (3) Once the participant was delayed in his response and lost touch with the forum postings for a while, he (she) would come back to find the number of postings too many to read. He (she) would notice that the thoughts that he (she) had thought of, had already been shared by others. This might discourage him (her) from posting the 'little' that he had thought.

Critical thinking as measured by CAIS model, showed the majority of the student postings were in the lower phases of critical thinking. In this study, the problems were ill-structured and the participants were encouraged to discuss on the problem that they were required to solve and decide on the learning issues they had to learn collaboratively. The researcher was concerned that the percentage of high level critical thinking postings was relatively low. But the results were at par with the results reported by Garrison et al (2001), Kosiak (2004) and Schrire (2006) in their study of online DFs.

Conclusions

The study showed that (1) critical thinking could be encouraged with the support offered by instructors and peers (2) ill-structured problems, Socratic question scaffolds served as sources of motivation for the learner, (3) critical thinking was encouraged when learners were encouraged to solve with reasoning over the DFs rather than simply solve the problem, and (4) student participants could collaborate to learn and enhance their thinking, while enjoying the challenge of collaboration.

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