Full paper

Using an automated tool to measure evidence of critical thinking of individuals in discussion forums.

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Abstract

Discussion forums are more frequently being used to promote a sense of community and encourage active participation in blended and online learning environments. Transcripts from discussion forums, which can be saved in electronic format, provide a rich source for academic research. Discussion forum transcripts are often analysed to identify evidence of collaboration and critical thinking. Critical thinking is described as reasonable, reflective, responsible, and skillful thinking that is focused on deciding what to believe or do. Critical thinking is viewed as an important attribute for success in the 21st century.

This paper looks at the importance of critical thinking as an educational objective and describes some of the tools that have been used to measure critical thinking. Tools which include automated tools and uses "content analysis" methods to analyse transcripts of discussion forums. The paper concentrates on a particular automated tool designed to measure evidence of critical thinking among discussion forum transcripts and in this case examines its ability to measure evidence of critical thinking for individual participants. The paper compares the results obtained using the tool with those obtained from a more traditional critical thinking measurement tool.

Keywords: Critical thinking, discussion forums, content analysis.

1 Introduction

Most educationalists would agree that critical thinking is an important element of life success in the information age (Thomas & Smoot, 1994). The use of discussion forums to support the delivery of fully on-line and blended educational courses is increasing (Romiszowski & Mason, 2004) and discussion forums are often promoted as a tool that can encourage critical thinking among participants. The use of asynchronous communications tools to promote interaction and help establish community is well documented (Sparturiu, Hartley & Bendixen, 2004), as is the use of discussion forums to promote critical thinking and knowledge construction (Kanuka & Anderson, 1998; Kirschner, Strijbos & Bears, 2004). The literature suggests that a number of researchers have attempted to measure evidence of critical thinking among discussion forum participants (Garrison, Anderson & Archer, 2001; Goodell & Yusko, 2005; Hara, Bonk & Angeli, 1998; Kanuka, 2002; Meyer, 2003).

Critical thinking skills are often touted as indicators of higher learning and are regularly cited as aims or outcomes of tertiary educational institutes. Oliver (2001) argues that critical thinking skills represent an important issue for the university sector and that critical thinking skills should be a primary focus of the degree level graduate profile. While critical thinking is recognized as an essential outcome of the educational process, little is being done to measure evidence of critical thinking within many educational programmes.

While there is documented evidence of efforts made to identify aggregate measures of group engagement indicators of critical thinking within discussion forums, it appears that little has been done to measure evidence of critical thinking by individuals (Perkins & Murphy, 2006).

This paper looks at the position of critical thinking as an educational goal and identifies some of the more commonly accepted tools used to measure critical thinking in both the face to face and on-line educational settings. The paper then concentrates on the measurement of critical thinking within discussion forums, building on previous studies by Corich, Kinshuk and Hunt (2004, 2006 and 2007) and describes how an automated content analysis tool (ACAT) was used to attempt to measure evidence of critical thinking for individual discussion forum contributors. The paper describes the use of the ACAT system and how it was used to analyse the transcripts of a group of individual students. The paper also compares the results obtained using the ACAT system with measurements obtained for the same group of students using a more traditional critical thinking measurement tool. The paper concludes by identifying areas for further research, and describes how the ACAT system could be further developed to make the automated tool easier to use and more likely to be adopted as a means of improving critical thinking among discussion forum participants.

2 Critical Thinking

The encouragement of critical thinking skills among college and university students has gained popularity in recent years. The use of the term “critical thinking” first emerged in the early 1980s and critical thinking has become a desired attribute for society as we have moved

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into the 21st century (Ennis, 2003). The historical roots of critical thinking can be traced back to Socrates and the Socratic Method. The Socratic Method is a philosophy that encourages people to rectify inconsistent and irrational thought processes, including confused meanings, inadequate evidence, contradictory beliefs and empty rhetoric (Paul, Elder & Bartell, 1997). The Socratic Method established the importance of seeking evidence, closely examining reasoning and assumptions, analyzing basic concepts, and tracing out implications. The practice of Socrates was followed by the critical thinking of Plato, who recorded the thoughts of Socrates. Plato was followed by Aristotle, and the Greek skeptics, who emphasized that things are often very different from what they seem to be and that only the trained mind is prepared to see through the way things look to us on the surface to the way they really are beneath the surface (Paul, Elder & Bartell, 1997).

In the 20th Century William Graham Sumner published a study of the foundations of sociology and anthropology in which he documented the tendency of the human mind to think sociocentrically and the parallel tendency for schools to serve the function of social indoctrination. He also recognized the deep need for critical thinking in life and in education. Another educator said to have significantly influenced the development of educational and critical thinking in the twentieth century was John Dewey (Smith, 1997). Dewey believed that that education must engage with and enlarge experience and that an educator's role was to encourage students to think and reflect. The influence of Dewey is evident in the writings of Coyle, Kolb, Lindeman and Rogers, educationalists that suggest that learning should be experiential, student focused and concerned with the development of critical and analytical thinking.

The concept of critical and analytical thinking has gained popularity among modern educationalists. Robert Ennis, Stephen Norris, John McPeck, Richard Paul, Harvey Seigel and Peter and Norren Facione are some of the more recognizable authors who have encouraged the adoption of critical thinking concepts in education. Today critical thinking is recognized as one of the main goals in education (Schafersman, 1991) and yet many educational institutes fail to encourage their learners to be reflective and think critically.

There are many definitions of the term "critical thinking". Chance (1986) described critical thinking as the ability to analyze facts, generate and organize ideas, defend opinions, make comparisons, draw inferences, evaluate arguments and solve problems. Scriven & Paul (1992) describe critical thinking as the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. More recently Robert Ennis (2004) defined critical thinking as a term that means reasonable and reflective thinking focused on deciding what to believe and what to do. He identified a number of characteristics that are common to critical thinkers. The characteristics include; being; open minded and mindful of alternatives; attempting to be well-informed; able to judge well the credibility of sources; able to identify, conclusions, reasons, and assumptions; and able to judge well the quality of an argument, including its reasons, assumptions and evidence. He also suggested that critical thinkers would be likely to be able to develop and defend a reasonable position; ask clarifying questions; formulate plausible hypotheses; plans experiments well; define terms in a way appropriate for the context and draw conclusions when warranted.

With the increasing acceptance of the importance of critical thinking, educational institutes have added the requirement for the encouragement of critical thinking to their graduate profiles and educationalists have attempted to design tools to identify levels of critical thinking (Jones, 1993). Some of the more commonly used critical thinking tools include:

- The California Critical Thinking Skills Test: College Level (1990) by Peter Falcione.
- The California Thinking Dispositions Inventory (1992) by Peter and Norren Facione.
- Cornell Critical Thinking Test, Level Z and X (2005) by Robert Ennis and Jason Millan.
- Critical Thinking Interview (1998) by Gail Hughes and Associates.
- The Ennis-Wier Critical Thinking Essay Test (1985) by Robert Ennis and Eric Wier.
- ICAT Critical Thinking Essay Examination (1996) by International Centre for Assessment of Thinking.
- Cambridge Thinking Skills Assessment (2003) by Cambridge University.

These critical thinking tests report on various critical thinking characteristics and have been used to measure an individual's level of critical thinking in both the educational and vocational environments.

3 Critical Thinking in Discussion Forums

Despite the growing popularity of the use of online tools such as discussion forums for blended learning and distance education there is limited empirical evidence to suggest that such tools facilitate higher level thinking (Bullen, 1998). While a number of researchers have developed models for measuring various aspects of critical thinking among discussion forum participants, few studies have focused specifically on critical thinking (Perkins & Murphy, 2006). Of the models that have been used to measure critical thinking, most have been applied to groups of participants measuring aggregate group performance; very few studies have attempted to measure an individual's critical thinking activities.

Perkins & Murphy (2006) reviewed a number of models developed to measure aspects of critical thinking. All the models that they reviewed used content analysis methods to attempt to classify discussion forum transcript entries into one of a number of categories shown, by making a judgment call as to which category a posting belongs. All the models are similar in that they all refer to clarification, making inferences, and making reference to providing and assessing evidence (Perkins & Murphy, 2006). The

process of categorization is described by many that use it "as difficult, frustrating, and time-consuming" (Rourke, Anderson, Garrison & Archer, 2001, p12). Agreement between coders varies considerably and very few researchers duplicate their original models to validate their findings. Rourke & Anderson (2002) suggest that the classification task is inherently subjective, inductive and prone to errors. The subjectivity arises from the interpretation of coders as they attempt to assign topics to categories. To reduce the likelihood of subjectivity during coding, researchers employ multiple coders and compare coding results to ensure that they come to the same coding decisions (Rourke et al., 2001). The most commonly used method of reporting reliability between coders is the percent agreement statistic, which reflects the number of agreements per total of coding decisions. Hosti (1969) coefficient of reliability and Cohen's kappa statistic are two of the more popular methods of reporting coding reliability (Rourke et al.,2001). Acceptable levels of agreement have yet to be established, with some researchers stating that anything less than 80% is unacceptable (Riffe, Lacey & Fico, 1998) while others report levels as low as 35% (Garrison, Anderson, & Archer (2001).

4 Automated Measuring Tools

Despite the fact that most discussion forums produce transcripts in a in a machine readable format, a review of current literature would suggest that there is little evidence of using computers to assist with the analysis (McKlin, Harmon, Evans & Jones, 2002). There are a number of well known software tools that can be used to assist in the task of analyzing text. These text-analysis tools include Wordnet, WordStat, NUD*IST, HyperQual and General Inquirer (Rourke et al., 2001). The tools are primarily text-processing systems which identify words as units and tend to be language-independent. The more powerful tools allow researchers to break a transcript into units and assign the units to a number of different coding categories. Once the transcripts have been coded, the results can be imported into statistical programs for more detailed quantitative analysis. The majority of automated text-analysis tools are generic and can be applied to a number of text analysis situations. Since the tools are generic, they do not come with built-in pre-existing word categories that could be applied to categorize cognitive activities and critical thinking; they rely on the researcher to create word categories.

McKlin et al.,(2001) recognizing the time saving benefits that could be gained by automating the transcript analysis process and wanting to attempt to reduce the subjectivity of human coding classification, designed an automated tool that used neural network software to categorize messages from a discussion forum transcript. They suggested that the tool may ultimately be used to gauge, guide, direct and manipulate the learning environment. The tool was based on Garrison, Anderson & Archer's (2001) Community of Enquiry model which classifies postings into four levels of critical thinking activity. The study reported coefficient of reliability figures of 84% and 76% when compared to results of human coders, suggesting that a neural network has the potential to successfully code transcripts to identify cognitive presence.

Yi-fang Brooke Wu and Xin Chen (2005) described how they developed an automated system which used automated text processing techniques to predict the class performance of students. The system measured keyword contribution, message length, and message count to calculate a performance indicator. The experimental results showed that the automated assessment model was able to produced results similar to those produced by human coders.

Corich, Kinshuk & Hunt (2006) describe the development of an automated content analysis tool (ACAT). Like the system developed by McKlin et al., the ACAT system was based on the Garrison et al., (2001) Community of Enquiry model. The ACAT system used Bayesian probability methods to classify participant postings into four categories of critical thinking activity. The system calculated measures of critical thinking based on raw text; text with stopwords removed and stemmed text, and was found to be able to produce results, which when compared to manually coded results, achieved a coefficient of reliability of as high as 71%.

The systems developed by McKlin, Wu and Chen, as well as the ACAT system developed by Corich et al., measured aggregate measures of group engagement. The results suggested that automated tools had the potential to produce coding classifications similar to those produced by human coders. All three systems were based on the Community of Inquiry model (Garrison et al., 2001), which focused on "critical thinking within a group dynamic as reflected by the perspective of a community of enquiry" (Garrison et al., 2001, p. 11). Perkins & Murphy (2006) suggest that the focus on the group dynamic is pertinent when the goal is to examine evidence of critical thinking in the online community as a whole. They questioned whether this approach would be relevant in cases where the focus is on the individual member of the online community.

The ACAT system described by Corich et al., (2006) was modified and used to measure evidence of critical thinking for individuals again using the Garrison Community of Inquiry model. Corich, Kinshuk & Hunt (2007) describes the results of the study. The study found that while the Community of Inquiry model was able to measure evidence of critical thinking for a group of participants it was not as successful at measuring evidence of critical thinking for individuals.

5 Using ACAT to Measure Individual Levels of Participation

The ACAT system described by Corich et al., (2007) had a number of modules that enabled discussion forum transcripts to be imported, parsed and classified by searching for linguistic markers that indicated that postings belonged to one of the four categories of the Garrison et al., Community of Enquiry model. The reporting module of the ACAT system was modified so that it could report results for the aggregate group as well as for individual participants. Since the original ACAT

system had the potential to be trained for any classification model, the resulting system also has the potential for being used to test a number of different models.

The study described in this paper attempts to measure evidence of critical thinking for individual participants using a model described by Perkins and Murphy (2006) which was specifically design to measure individual participation. The Perkins and Murphy (2006) model used four critical thinking indicators. To test the validity the results of the ACAT system using the Perkins and Murphy (2006) model a traditional critical thinking test was used to measure the critical thinking skills of the discussion forum participants and results for the two systems were compared.

6 Methodology

The discussion forum transcripts used in this study were obtained from a discussion forum used in a third year undergraduate Web Development course which took place in the first semester of 2007. The transcripts were obtained with ethical approval of the institute and involved sixteen students, aged between 18 and 36, and of varying academic abilities. All participants signed consent forms agreeing to participate in the study. The course was delivered using a blended learning environment, combining traditional face-to-face activities with web publishing, on-line review and discussion forum activities. The discussion forum activity was assessed and given a 15% weighting for the final assessment allocation. Students were asked to discuss the "Web Hosting Environments" and they were informed that they would be expected to demonstrate aspects of critical thinking in their posts. Prior to the commencement of the discussion forum activity, students were given a marking rubric that indicated the type of activities that would be recognized as contributing to the four different levels of critical thinking (clarification, assessment, inference and strategies).

The software used to support the discussion forum was an integral part of the Moodle learning management system, which allows the discussion forum transcripts to be exported as individual text files for each participant. All students had previously used the Moodle learning management system and most students had participated in an assessed discussion forum earlier in their studies.

During the three week period when students were expected to post to the forum, an instructor monitored postings on a daily basis. The instructor provided encouragement, added pedagogical comments and provided reinforcement and expert advice. Of the 16 students, only 12 participated in the discussion and then went on to participate in the critical thinking test. 142 student posts were made which generated 436 sentences for coding. The resulting transcripts were reviewed by a human coder who removed 148 of the sentences which were viewed as being social in nature or not contributing to the discussion topic, leaving 288 sentences for manual and automatic analysis.

The human coder then manually coded the sentences for each individual using a rubric based on the Perkins and Murphy (2006) model, where sentences are categorized as belonging to one of the clarification, assessment, inference and strategies categories. The 288 sentences were imported into the ACAT system, and the system was used to categorise the postings and produce individual reports for each of the participants.

Following the completion of the discussion forum exercise the 12 students who had participated in the discussion forum were asked to complete the Cambridge Thinking Skills Assessment demonstration test.

7 Results & Findings

The tables below (tables 1 and 2) show the results of the analysis of the 288 sentences obtained from the discussion forum transcripts after the social and non-contributing sentences had been removed. Table 1, represents the individual participants critical thinking classifications, as a percentage, as agreed by the human coder.

Table 1: Human Coder: Individual participant classification as a percentage using the Perkins and Murphy (2006) model

	sentences	clarification	assessment	inference	strategies
1	18	27.8	27.8	22.2	22.2
2	26	30.8	23.1	26.9	19.2
3	19	26.3	26.3	36.8	10.5
4	21	23.8	28.6	28.6	19
5	24	29.2	29.2	29.2	12.5
6	28	32.1	39.3	14.3	14.3
7	30	26.7	30	20	23.3
8	19	31.6	26.3	31.6	10.5
9	27	33.3	37	18.5	11.1
10	25	28	28	24	20
11	31	32.3	32.3	19.4	16.1
12	20	30	30	30	10

Table 2, represents the individual participants critical thinking classifications, as a percentage, coded by the ACAT system.

Table 2: ACAT System: Individual participant classification as a percentage using the Perkins and Murphy (2006) model

	sentences	clarification	assessment	inference	strategies
1	18	27.8	33.3	16.7	22.2
2	26	30.8	26.9	23.1	19.2
3	19	26.3	26.3	36.8	10.5
4	21	28.6	23.8	23.8	23.8
5	24	29.2	25	33.3	12.5
6	28	28.6	39.3	21.4	10.7
7	30	30	26.7	23.3	20
8	19	31.6	21.1	36.8	10.5
9	27	33.3	33.3	18.5	14.8
10	25	28	24	28	20
11	31	25.8	32.3	22.6	19.4
12	20	30	30	35	5

The coefficient of reliability between the manually coded

results and the automatically coded results was 72% which compares with the earlier results of 71% (Corich et al. 2006) and 73% (Corich et al. 2007). Like the 2007 study sentences which were viewed as being social in nature or not contributing to the discussion topic were removed prior to analysis, and the manual coders listed them as uncategorized. For the 2006 study no sentences were removed and the automatic system placed them into the category with the highest matching probability.

Like the 2007 study, the results produced by human coders for individual are similar to those produced by the ACAT system. This would tend to reinforce the suitability of the ACAT system for providing useful information about the critical thinking activities of individual participants within a discussion forum.

Unlike the 2007 study, this study indicates differences in levels of critical thinking between different individual participants. This tend to supports the findings made by Perkins and Murphy (2006) that the model they had developed to specifically measure evidence of critical thinking for individuals provided a better indicator of an individual's critical thinking than the Garrison et al., Community of Enquiry model.

Table 3, represents the results of the Cambridge Thinking Skills Assessment demonstration test for the same individuals that participated in the discussion forum activities.

Table 3: Cambridge Thinking Skills Assessment demonstration test results

Participant	Score
1	65
2	60
3	51
4	65
5	55
6	48
7	64
8	55
9	52
10	63
11	61
12	45

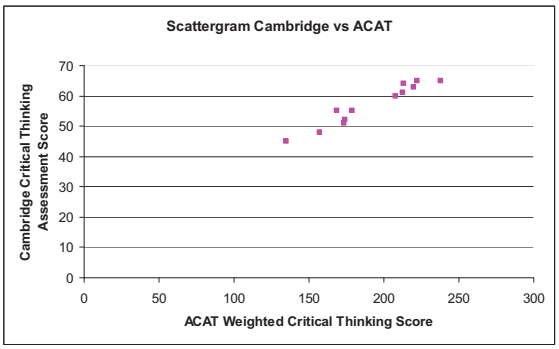
The scores from the Cambridge Thinking Skills Assessment demonstration test would suggest that the participants in the study varied in their critical thinking skills abilities. The results obtained from the manual coding and automated coding of transcripts also indicated different levels of critical thinking. Since the results from the manual coding and the ACAT coding do not indicate an overall critical thinking score which can be compared to the Cambridge Thinking Skills Assessment results, an algorithm was used calculate a score that recognizes higher levels of critical thinking for the ACAT system produced results. The algorithm applies weightings to each of the four categories (lower weightings for the lower level categories and higher weightings for the higher level categories), multiplies the percentages in each category by the weightings and totals the result to arrive at a cumulative score for each participant. Table 4 shows the calculated total score for the ACAT system results.

Table 4: Calculated cumulated score for the ACAT system

Participant	Score
1	222.2
2	207.7
3	173.7
4	238.1
5	179.2
6	157.1
7	213.3
8	168.4
9	174.1
10	220
11	212.9
12	135

Figure 1 represents a scattergram showing the relationship between the Cambridge Thinking Skills Assessment score and the ACAT system weighted score. The chart suggests a strong correlation between the two sets of results.

Figure 1: Scattergram of Cambridge Thinking Skills Assessment score and the ACAT system weighted score



To test the correlation between the two scores Spearman's Rank Correlation Coefficient was calculated. The Spearman's Rank Correlation Coefficient appeared to be the most appropriate measure of correlation or association for the study.

The Spearman correlation coefficient was 0.954 suggesting a strong correlation between the scores for the Cambridge Thinking Skills Assessment and the ACAT system.

8 Discussion

The purpose of this study was to evaluate if an automated content analysis tool could be used to identify levels of critical thinking by individual participants in a discussion forum and to validate the results against a traditional measure of critical thinking. Since the sample size was small, generalizations cannot be made on the basis of the

findings. The results however do suggest that the use of automated tools for identifying levels of critical thinking in discussion forums is worthy of further research.

The strong correlation between the results obtained using the ACAT system with the Perkins & Murphy model and the results obtained using the Cambridge Thinking Skills Assessment (Spearman coefficient = 0.954) suggest that the ACAT system provides an indication of critical thinking that is similar to that produced by the Cambridge Thinking Skills Assessment.

The study adds credibility to the Perkins & Murphy model and reinforces the findings described in the paper presented in the Educational Technology & Society Journal in 2006.

9 Conclusions and Further Research

The results of using the ACAT system for categorising indicators of critical thinking for individual discussion forum participants suggest that the automated system has the potential for further investigation and development. Once again the automated coding system compared favourably with the coding conducted by human coders.

The model developed by Perkins and Murphy (2006), appeared to provide a tool that was able to identify evidence of critical thinking for individuals. The strong correlation between ACAT system results and the Cambridge Thinking Skills Assessment scores would suggest that the Perkins and Murphy model does provide an accurate indicator of an individual's critical thinking abilities.

Since the ACAT model has proven successful at categorising indicators for critical thinking for individuals there is the potential to incorporate the model into a learning management system such as Moodle and provide a tool that will allow individual discussion forum participants to check the level of their critical thinking abilities. Such a tool would have the potential to guide participants and suggest ways of improving the level of their critical thinking.

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