

# Computerised Content Analysis for Measuring Critical Thinking within Discussion Forums

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## Abstract

The growing popularity of online education has seen an increasing acceptance of the use of discussion forums as a means of promoting collaboration and interaction among distance education students. The fact that transcripts of these discussion forums can be saved as a permanent digital record has provided researchers an opportunity to analyse the interactions among participants and investigate evidence of cognitive and metacognitive activity.

This paper investigates some of the methodologies adopted by researchers who have attempted to analyse discussion forum transcripts, concentrating on methodologies that attempt to measure cognitive processes and critical thinking. It also investigates the use of computers in the content analysis process and describes how a tool using neural network has been successfully used to analyze transcripts.

The paper introduces a computerized tool, which aims to allow different content analysis methodologies to be compared.

The paper will be of interest to those who use discussion forums in their teaching activities and wish to measure the cognitive processing activities of discussion forum participants.

## 1. Introduction

The growing popularity of online learning and its increasing acceptance as an educational tool among tertiary educators is well documented (Spatariu, Hartley & Bendixen, 2004; Green, 2000). The use of discussion forums as a means of promoting discourse between online learning participants has also been the subject of several academic studies (Henri, 1991; Gunawardena, Lowe & Anderson, 1997; Newman, Webb & Cochrane, 1995; Garrison, Anderson & Archer, 2000; Hara, Bonk & Angeli, 2000). Researchers investigating the use of asynchronous discussion forums have attempted to identify evidence of critical thinking, which, as Bloom et al. (1956) suggested, should be a prime objective of any form of education, including online learning. A number of models, the majority of them based loosely on Bloom's taxonomy, have been documented and tested. These models have attempted to measure the extent to which knowledge is constructed through the collaborative discourse among discussion forum participants.

This paper describes a research study to measure the quality of participation in discussion forums. It concentrates on one of the commonly adopted methodologies, quantitative content analysis, and discusses some of the issues surrounding its use.

The paper then considers some of the systems that could be used to automate the process of content analysis focusing on a computerized system that measures participation using neural networks. The paper also looks at the design of an alternate computerized content analysis system based on Bayesian Networks, and discusses the potential of such a system to identify evidence of cognitive activity and critical thinking by forum participants. The paper concludes by discussing the likely development path for such a system and suggests opportunities for its use and future modification.

## 2. Background

The increased use of online discussions in recent years within courses that are exclusively online or use online technologies to enhance on-campus courses is clearly identified by Meyer (2004). One of the benefits associated with the use of online discussions is that a written record of activity is created that can be referred to by students for reflection. These written records can also be studied by academics who may wish to investigate the types of interactions between participants (Meyer, 2004).

The analysis of discussion forum transcripts has been the subject of academic research for some time and several models have been developed that attempt to measure the dynamics of discussion forum activity (Fahy et al., 2000; Garrison, Anderson & Archer, 2001; Gunawardena, Lowe & Anderson, 1997; Kanuka & Anderson, 1998; McKlin et al., 2002; Newman, Webb & Cochrane, 1995; Henri,

1991). A number of different approaches have been used to attempt to identify participation in online discussions. Spatariu, Hartley & Bendixen (2004), having reviewed current literature, suggested that the majority of studies can be loosely organised into one of the four categories, according to the construct being measured: levels of disagreement, argument structure analysis, interaction-based, and quantitative content analysis.

Studies belonging to the level of disagreement category adopt the approach of coding messages according to the level of disagreement that is exhibited in relation to previous posting. Researchers who used this method include Marttunen (1998) and Nussbaum et al. (2002). The argument structure analysis category codes messages according to the argument quality demonstrated by participants. Researchers that have adopted this approach include Inch & Warnick (2002) and Veerman, Andriessen & Kanselaar (1999). Interaction-based coding methods place an emphasis on the message as part of a larger discussion. Schaeffer et al. (2002), Järvelä & Häkkinen (2002) and Nurmela, Lehtinen & Palonen (1999) have adopted this approach. The content analysis approach codes messages according to the message type. A review of literature suggests that quantitative content analysis (QCA) is the most popular approach used by researchers to evaluate quality in discussion forum postings. The more commonly cited researchers include Henri (1992), Gunawardena, Lowe & Anderson (1997), Newman, Webb & Cochrane (1995), Garrison, Anderson & Archer (2000) and Hara, Bonk & Angeli (2000).

### 3. Quantitative content analysis

Quantitative Content Analysis (QCA) is described as «a research technique for the objective, systematic, quantitative description of the manifest content of communication» (Berelson, 1952, p. 519). In its simplest form, QCA involves breaking transcripts into units, assigning the units to a category and counting the number of units in each category. QCA is described by many, who have used it, as «difficult, frustrating, and time-consuming» (Rourke et al., 2001, p. 12). Agreement between coders varies considerably and very few researchers duplicate their original models to validate their findings. There are however examples where researchers have adopted and modified existing models (Bullen, 1999; Hara, Bonk, & Angeli, 2000; McDonald & Gibson, 1998; Zhu, 1996). There are far fewer examples where researchers adopted an existing model and tested it without modification, as a means of validating the model. Meyer (2004) and Corich, Kinshuk & Hunt (2004) provide examples where existing models have been used and results are compared to original studies.

Researchers applying QCA to discussion forum transcripts have measured a number of different variables, including participation, social interaction, cognitive elements, metacognitive elements, group development, participant roles, collabora-

tive learning and critical thinking. Rourke et al. (2001) suggested that cognitive processes and critical thinking are the most commonly measured variables. Those who have measured cognitive processes include Henri (1991), Kanuka & Anderson (1998), Anderson & Kanuka (1997), Hara, Bonk & Angeli (2000) and McDonald & Gibson (1998). Those who have measured critical thinking include Newman, Webb, & Cochrane (1995), Weiss & Morrison (1998), Garrison, Anderson, & Archer (2000), Fahy et al. (2000), and Bullen (1998). Educationalists argue that cognitive presence and critical thinking are essential objectives for all educational activities including distance education (Bloom et al., 1956; Haughly & Anderson, 1998). Perhaps this explains the large number of researchers who have analyzed discussion forum transcripts attempting to find evidence of cognitive activities and critical thinking (Rourke et al., 2001).

Detection of critical thinking in discussion forum activity is a difficult task (Fahy, 2002). Researchers attempting to identify evidence of critical thinking look for traces or indicators of higher-level cognitive activity within forum transcripts. This task is said to be inherently subjective, inductive and prone to errors (Rourke & Anderson, 2002). 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., 2000). 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's coefficient of reliability (Hosti, 1969) and Cohen's kappa statistic are two of the popular methods of reporting coding reliability (Rourke et al., 2000). 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, 2000).

#### 4. Computerised text analysis tools

The written transcripts produced as a result of activities among participants in a discussion forum can usually be exported to text file that can then be subjected to quantitative content analysis. A review of literature suggests that even though the output is produced in a machine readable format, there is little evidence of using computers to assist with the analysis (McKlin et al., 2001). There are a number of 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 vessels that identify words (characters bounded by spaces or punctuation) as units and, except for problems arising from the use of special alphabets, tend to be language-in-

dependent. 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 researchers to create word categories.

McKlin et al. (2001) described the use of an automated tool that uses 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 analysis was based on Garrison, Anderson & Archer's (2000, 2001) community of enquiry model. 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. The study also suggested that the tool would be refined to produce a system that could be used to reliably classify messages into cognitive presence categories. Despite a review of current literature and an attempt to contact the research team, no evidence could be found of further publications relating to the tool.

## 5. Automated content analysis tool (acat)

Considering the positive findings of McKlin et al. (2001), a decision was made to design and develop a web based automated content analysis tool (ACAT) that could be applied to discussion forum transcripts to identify evidence of critical thinking by discussion forum participants. The aim of the development is to produce a system that can be used to apply a number of recognized QCA models to categorize messages for differing levels of cognitive activity and critical thinking. The tool allows the analysis of both the group and the individual participants.

Figure 1 shows the ACAT concept model for the system. Users can import a transcript and then select one from a number of recognized quantitative content analysis (QCA) models. The system is then able to use the information related to the chosen model to analyze the text for evidence of cognitive activities and critical thinking, producing reports that show the number of units of activity that fit within each of the categories of the model.

The QCA management module allows users to define QCA models, edit and delete existing models and manually input category information for each model. The QCA training module allows an imported transcript to be parsed and manually coded against a QCA model. The transcript importing and parsing module

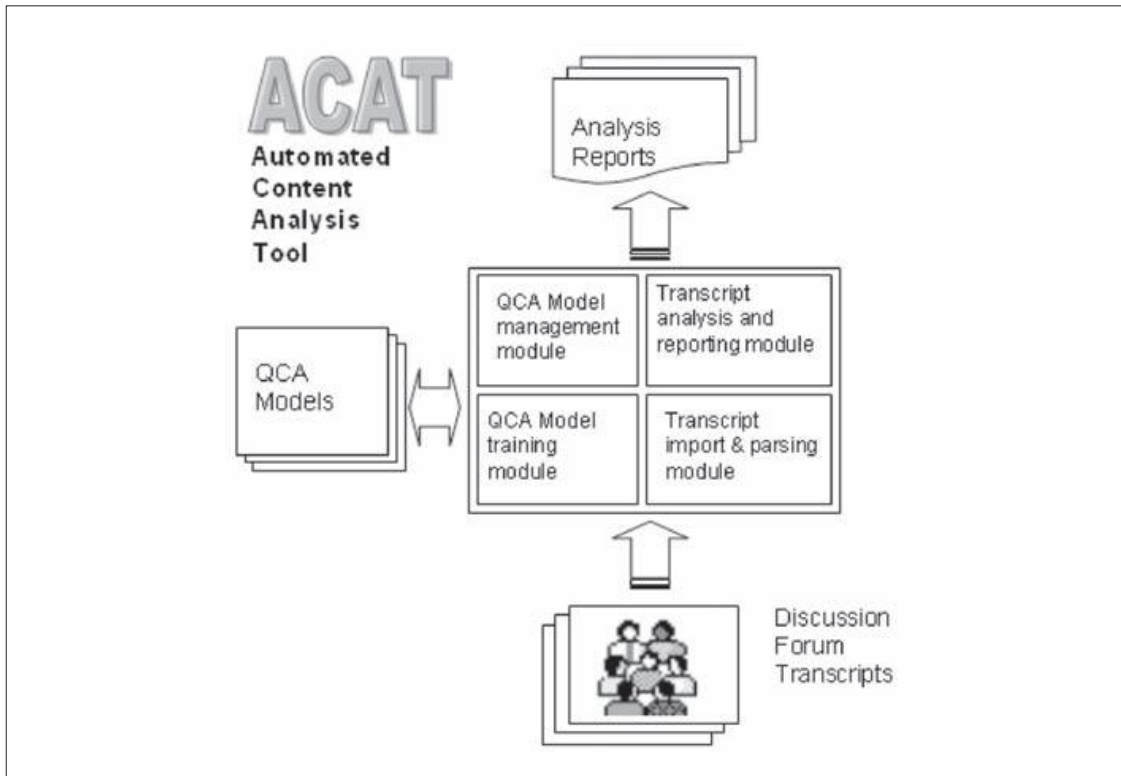


Figure 1 ACAT concept model.

imports forum transcripts, parsing them into analysis units and saving the individual units in a table ready for analysis. The transcript analysis and reporting module analyses each analysis unit, assigning it to one of the categories of the selected QCA model and then produces reports detailing the number of units applied to each category.

An advantage that the ACAT system offers over the system developed by McKlin et al. (2001), is that it allows the user to select one of a number of recognized QCA models and perform analysis based on information related to the model. In future, the system will also allow different models to be compared.

## 6. Analysis models

There are a number of models that have been used to measure cognitive activities and critical thinking. Corich et al. (2004) suggested that the methodologies proposed by Henri (1992) and Garrison, Anderson & Archer (2000) are two of the most popular content analysis approaches. These two methodologies have been either duplicated or incorporated into models developed by other researchers.

While the coding system used by Henri (1992) was not clearly defined in her research, it was used as the basis of subsequent research conducted by Hara,

Bonk & Angeli (2000). The cognitive and metacognitive components of Hara et al.'s analysis framework were well defined making it a model that can be readily reproduced. The cognitive component had five categories of cognitive activities: elementary clarification, in-depth clarification, inferencing, judgment and application of strategies.

The model developed by Garrison et al. (2000) was referred to as a «community of learning» model which assumes that learning occurs through the interaction of three core components: cognitive presence, teaching presence, and social presence. The cognitive presence concept was expanded by Garrison, Anderson, & Archer (2001) into a four stage cognitive-processing model, which was used to assess critical thinking skills in on-line discussions. The model classified student responses into triggering, exploration, integration and resolution categories. The framework for the Garrison et al. (2001) model was also well documented, making it easy to reproduce.

Corich et al. (2004) conducted a manual transcript analysis of a first year degree Data Communications course using these two models. The transcripts and coding results of these transcripts will be used to train the system when development is completed. Further models could be added once the system has been validated.

## 7. Analysis technique

While there is little evidence of using computers to classify the transcripts of discussion forums, several studies have reported favorably on the computer grading of essays (Page, 1966 & 1994; Landauer, Foltz & Latham, 1998; Chung & O'Neil, 1997). Rudner & Liang (2002) reported that there is promising literature in the information science field regarding the use of Bayes Theorem as the underlying model behind text classification. Bayesian networks have become widely accepted and are being used in essay grading systems, help desk applications, medical diagnosis, data mining, intelligent learning systems and risk assessment tools (Rudner & Liang, 2002). Bayesian networks use probability theory to assign items to various categories. McCallum and Nigam (1998) provide an excellent overview of the use of Bayesian networks.

The apparent success of using Bayesian networks to classify text suggests that a similar process could be applied to classify transcripts. The analysis technique adopted in ACAT development is based on an essay scoring system described by Rudner and Liang (2002) who used a four point scale to categorize the features of essays.

## 8. Unit of analysis

For any QCA exercise it is important to identify the segments of the transcript that will be categorized. Researchers have experimented with different units with

varying measures of success (Rourke et al., 2000). The units that have been used include sentences, paragraphs, messages and thematic units. Sentences have been used successfully by Fahy et al. (2000) and Corich et al. (2004), although Rourke et al. (2000) reported mixed success. Hara et al. (2000) used the paragraph as a measurement unit reporting lower levels of agreement than those reported by Fahy et al. (2000) and Corich et al. (2004). Marttunen (1997) and Garrison et al. (2000) used the message as their measurement unit reporting high levels of agreement between coders. Henri (1991) rejected the idea of using a fixed unit and she used a «unit of meaning». While this approach proved successful it would be difficult to consistently identify «units of meaning» using a computer. The ACAT system is developed to initially use the sentence as its unit of analysis, since it is easy to quantify using a software application. In future, the system may be extended to allow the choice of sentence, paragraph or message.

## 9. Reporting

The ACAT system provides statistical reports identifying the number of postings, the number of units analyzed, word frequencies and word sizes. For each analysis model the system displays the categories the model uses and the number of units that are categorized within each of the categories. The system also allows reports to be generated showing the dictionary of words and phrases for each category within each analysis model and the number of unit matches for each.

## 10. Acat system prototype

A web-based ACAT system prototype has been developed using PHP as the programming language with a MySQL backend database (Figure 2). The prototype imports transcripts from a variety of text sources (Figure 3). It allows users to add analysis models (Figure 4), create categories for analysis and build dictionaries of appropriate words and phrases for each category of the model (Figure 5). The system currently reports sentence and word frequencies and recognizes word and phrase matches within each of the categories of the model (Figure 6). The analysis agent is currently being engineered to incorporate the use of Bayes Theorem so that category matches can be determined using probability theory techniques.

## 11. Extension of the concept model and prototype

Once the analysis agent is completed, the system will be trained using the data from earlier manual transcript analysis exercises and the model will then be validated using the forum transcripts of current computing courses at the Eastern Institute of Technology of New Zealand. When the system has been validated, it is planned to add additional features that should improve the reliability of the



category classification. One of the planned additional features is a word stem recognition function. Word stemming, which is the process of removing suffixes from words to get the common origin of the word, is said to help when comparing texts to identify words with a common meaning and form as being identical (Hull & Grefenstette, 1996). Another planned feature is the use of a stopwords removal function, which involves the removal of words which are very frequent and do

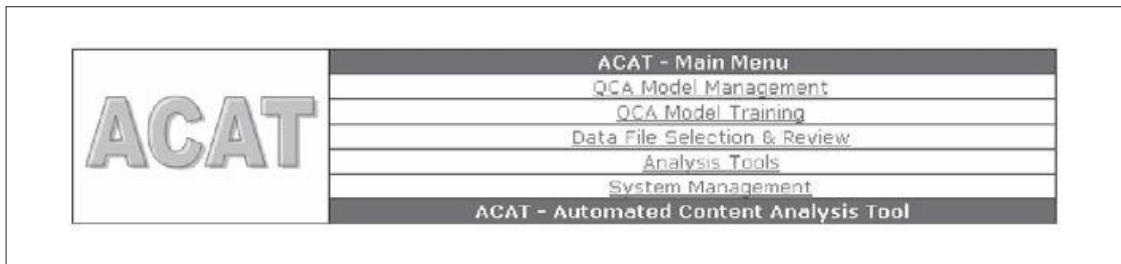


Figure 2 ACAT main menu screen.

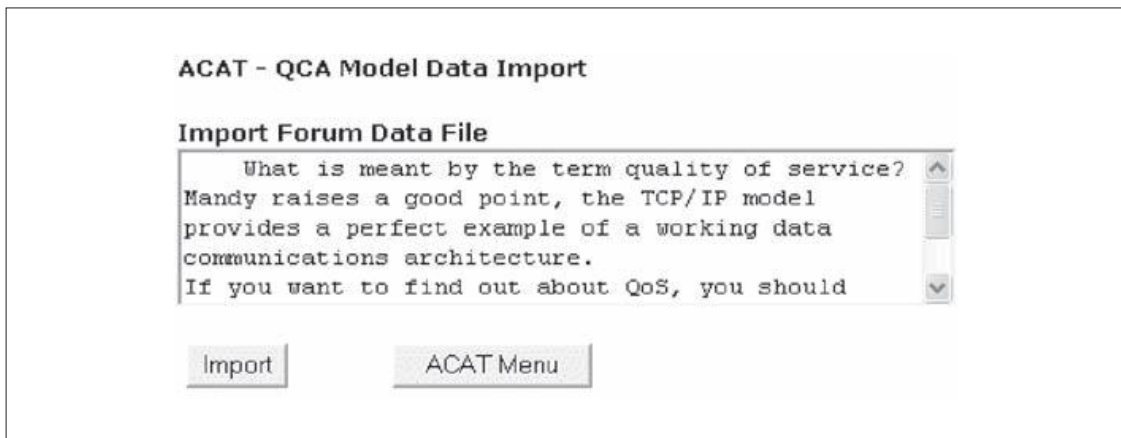


Figure 3 Transcript import screen.

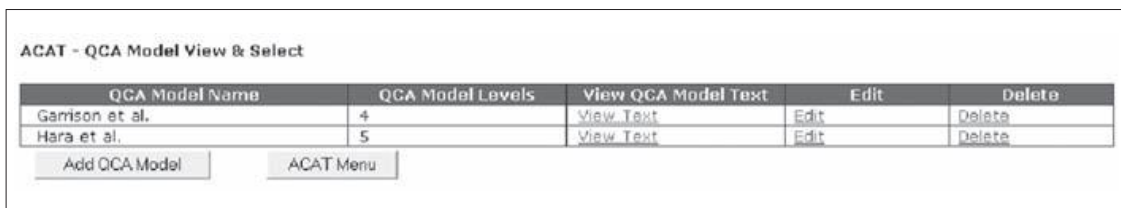


Figure 4 QCA model management screen.

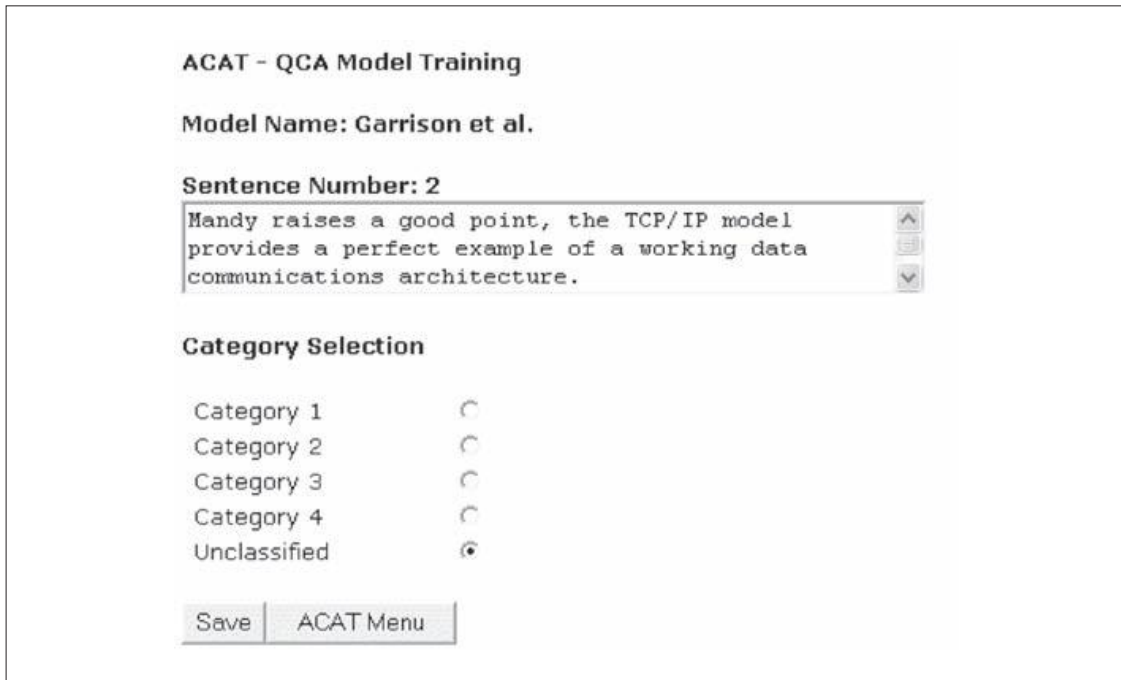


Figure 5 QCA Model Training Screen.

ACAT - Analysis Report	
Data Source	C:\wamp\www\forum\forum.txt
Analysis Type	QCA Model Analysis
QCA Model Type	Garrison et al.
Number of Categories	4
Analysis Statistics	
Number of Sentences	16
Word Count	216
Syllable Count	292
Character Count	932
Mean words per sentence	14
Mean syllables per sentence	18.25
Mean Characters per sentence	13.5
Mean syllables per word	1.35
Mean characters per word	4.31
Dictionary matches	92%
Content Analysis Results	
Level 1	3
Level 2	7
Level 3	4
Level 4	1
Unclassified	1
Graphical results display	
Display Chart	
ACAT - Automated Content Analysis Tool	

Figure 6 QCA model management screen.

not carry meaning. Like word stemming, stopword removal is said to improve the reliability and effectiveness of text analysis systems (Ginsparg et al., 2004). A third planned improvement will be the incorporation of a thesaurus, to help identify words with similar meanings which once again should help improve the effectiveness of the text analysis. Figure 7 shows the extended ACAT concept model.

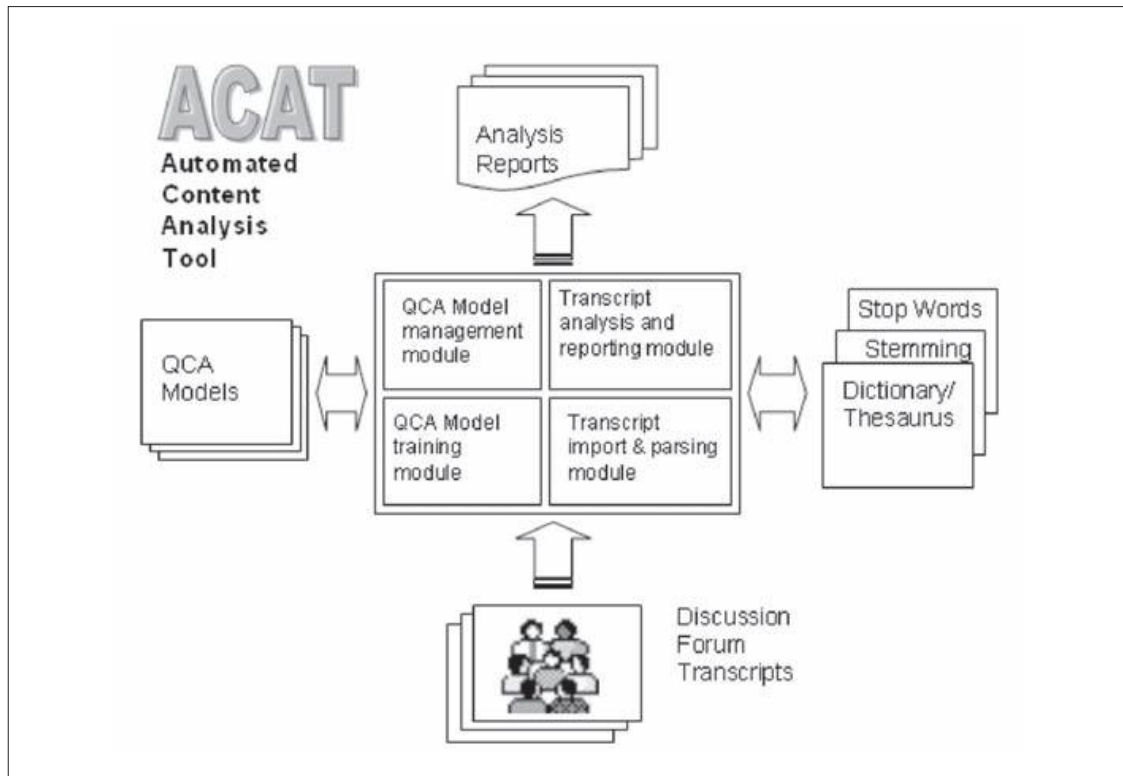


Figure 7 Extended ACAT concept model.

## 12. Conclusion

Discussion forums have become an integral part of the online learning and they are being used to enhance the experience of the distance learners. Discussion forums are gaining popularity as a mechanism for increasing student interaction in the on-line learning environment, where they are viewed as one of a range of tools that enable on-line course participants to collaborate, share ideas and discuss domain related concepts.

Many online course supervisors have adopted discussion forums as a tool to assist with assessment, incorporating them into assessment activities and allocating grades for active and effective participation.

The potential for using a computerized text analysis system designed specifically to work with discussion forum transcripts appear to have been ignored by

researchers who have been involved in the evaluation of discussion forum postings (McKlin et al., 2002).

A literature review of current research suggests that the majority of researchers continue to use manual methods to codify transcripts. If a computerized system is built and validated, it would have the potential to overcome some of the problems associated with manual coding. Problems such as coder interpretation could be avoided and the time involved in coding could be reduced significantly.

A computerized discussion forum transcript analysis tool is being developed that has the potential to provide immediate feedback to forum participants, providing advice on the level of participation and perhaps suggesting how the quality of activities could be improved.

Such a system could assist course supervisors with the grading of student activities, providing timely and accurate feedback on student interaction, cognitive behaviours and evidence of critical thinking.

## BIBLIOGRAPHY

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- Anderson, T. & Kanuka, H. (1997). On-line forums: New platforms for professional development and group collaboration. (ERIC Document Reproduction Service, ED 418 693).
- Berelson, B. (1952). *Content analysis in communication research*. Illinois: Free Press.
- Bloom, B.S., Englehart, M.D., Furst, E.J., Hill, W.H. & Krathwohi, D.R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook 1: Cognitive domain*. New York: David McKay Co. Inc.
- Bullen, M. (1999). Participation and critical thinking in online university distance education. *Journal of Distance Education*, 13(2),1-32.
- Chung, G.K., W.K., & O’Niel, H.F., Jr. (1997). Methodological approaches to online scoring of essays. ERIC Document Reproduction Service, No. ED 418 101, 39pp.
- Corich, S.P, Kinshuk & Hunt, L.M., (2004). Assessing Discussion Forum Participation: In Search of Quality. *International Journal of Instructional Technology and Distance Learning*, 1(12), 1-12.
- Fahy, P. (2002). Use of linguistic qualifiers and intensifiers in a computer conference. *American Journal of Distance Education*, 16(1).
- Fahy, P.J., Crawford, G., Ally, M., Cookson, P., Keller, V. and Prosser, F. (2000). The development and testing of a tool for analysis of computer mediated conferencing transcripts. *Alberta Journal of Educational Research*, 46(1), Spring, 85-88.
- Garrison, D.R., Anderson, T., & Archer, W. (2000). Critical thinking in a text-based environment. Computer Conferencing in higher education. *Internet in Higher Education*, 2(2), 87-105.

- Garrison, D.R., Anderson, T., & Archer, W. (2001). Critical Thinking, Cognitive Presence, and Computer Conferencing in Distance Education. *The American Journal of Distance Education* 15(1), 7-23.
- Ginsparg, P., Houle, P., Joachims, T., & Sul, J. (2004). Mapping subsets of scholarly information. *Proceedings of National Academy of Sciences of the United States of America* 101 (1), 5236-5240.
- Green, J. (2000). The online education bubble. *The American Prospect*, 11(22), 32-35.
- Gunawardena, C., Lowe, C. & Anderson, T. (1997). Analysis of a global on-line debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *Journal of Educational Computing Research*, 17(4), 395-429.
- Hara, N., Bonk, C., & Angeli, C., (2000). Content analyses of on-line discussion in an applied educational psychology course. *Instructional Science*, 28(2), 115-152.
- Haughly, M. & Anderson, T. (1998). *Networked Learning: The pedagogy of the Internet*. Montreal: Cheneliere/McGraw-Hill.
- Henri, F. (1991). Computer conferencing and content analysis. In A.R. Kaye (Ed.), *Collaborative learning through computer conferencing: The Najaden Papers* (pp. 116-136). Berlin: Springer-Verlag.
- Hosti, O. (1996). *Content analysis for social sciences and humanities*. Don Mills, ON: Addison Wesley.
- Hull, D.A., & Grefenstette, G.(1996) Stemming algorithms: A case study for detailed evaluation. *Journal of the American Society for Information Science*, 47 (1), 70-84.
- Inch, E. S., & Warnick, B. (2002). *Critical thinking and communication*. Boston: Allyn & Bacon.
- Järvelä, S., & Häkkinen, P. (2002). The levels of Web-based discussions – Using perspective-taking theory as an analysis tool. In H. Van Oostendorp (Ed.), *Cognition in a digital world* (pp. 77-95).
- Kanuka, H. & Anderson, T. (1998). Online social interchange, discord, and knowledge construction. *Journal of Distance Education*, 13(1), 57-75.
- Landauer, T.K., Foltz, P.W., & Latham, D. (1998). Introduction to Latent Semantic Analysis. *Discourse Processes*, 25, 259-284.
- Marttunen, M. (1998). Electronic mail as a forum for argumentative interaction in higher education studies. *Journal of Educational Computing Research*, 18, 387-405.
- McCallum, A. & Nigam, K. (1998). A comparison of event models for Naive Bayes text classification. In *AAAI-98 Workshop on Learning for Text Categorization*. Available online <http://citeseer.ist.psu.edu/mccallum98comparison.html>.
- McDonald, J., & Campbell Gibson, C. (1998). Interpersonal dynamics and group development in computer conferencing. *American Journal of Distance Education*, 12(1), 7-25.
- McKlin, T., Harmon, S.W., Evans, W., & Jones, M.G. (2002). Cognitive Presence in Web-Based Learning: A Content Analysis of Student's Online Discussions, Paper #60. ITFORUM: A Listserve for the Instructional Technology Community. Available Online: <http://it.coe.uga.edu/itforum/paper60/paper60.htm>.

- Meyer, K.A. (2004, April). Evaluating online discussions: four different frames of analysis. *Journal of American Learning Networks*, 8(2), 101-114.
- Newman, G., Webb, B., & Cochrane, C. (1995). A content analysis method to measure critical thinking in face-to-face computer supported group learning. *Interpersonal Computing and Technology*, 3(2), 56-77.
- Nurmela, K., Lehtinen, E., & Palonen, T. (1999). Evaluating CSCL log files by social network analysis. In C. Hoadly & J. Roschelle (Eds.), *Proceedings of the Third Conference on Computer Supported Collaborative Learning* (pp. 443-444). Stanford, CA: Stanford University.
- Nussbaum, E.M., Hartley, K., Sinatra, G.M., Reynolds, R.E., & Bendixen, L. (2002, April). *Enhancing the quality of on-line discussions*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Page, E.B. (1994). Computer Grading of Student Prose, Using Modern Concepts and Software. *Journal of Experimental Education*, 62(2), 127-142.
- Page, E.B. (1996). Grading essays by computer: Progress report. *Notes from the 1996 Invitational Conference on Testing Problems*, 87-100.
- Riffe, D., Lacey, S., & F. Fico (1998). *Analyzing media messages: Using quantitative content analysis in research*. Mahwah: New Jersey.
- Rourke, L., Anderson, T., Garrison, D.R., & Archer, W. (2001). Methodological issues in the content analysis of computer conference transcripts. *International Journal of Artificial Intelligence in Education*, 12(1), 8-22.
- Rourke, L., & Anderson, T. (2002). Exploring social communication in computer conferencing. *Journal of Interactive Learning Research*. June.
- Rudner, L.M., & Liang, T. (2002). Automated Essay Scoring Using Bayes' Theorem. *National Council on Measurement In Education*. New Orleans, April.
- Schaeffer, E.L., McGrady, J.A., Bhargava, T., & Engel, C. (2002, April). *Online debate to encourage peer interactions in the large lecture setting: Coding and analysis of forum activity*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.
- Spatariu, A., Hartley, K. & Bendixen, L.D. (2004, Spring) Defining and Measuring Quality in On-line Discussion. *Journal of Interactive Online Learning*, 2(4).
- Veerman, A.L., Andriessen, J.E.B., & Kanselaar, G. (1999). *Collaborative learning through computer-mediated argumentation*. In C. Hoadly & J. Roschelle (Eds.), *Proceedings of the third conference on Computer Supported Collaborative Learning* (pp. 640-650). Stanford, CA: Stanford University.
- Weiss, R., & Morrison, G. (1998). Evaluation of a graduate seminar conducted by listserv. (ERIC Document Reproduction Service No. ED 423 868).
- Zhu, E. (1996). Meaning negotiation, knowledge construction, and mentoring in a distance learning course. (ERIC Document Reproduction Service No. ED 397 849).