Developing a comprehensive metric for assessing discussion board effectiveness

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Abstract

The use of online discussion boards has grown extensively in the past 5 years, yet some researchers argue that our understanding of how to use this tool in an effective and meaningful way is minimal at best. Part of the problem in acquiring more cohesive and useful information rests in the absence of a comprehensive, theory-driven metric to assess quality and effectiveness. Based on an extensive review of the research, the following variables were used to assess traditional discussion board use: thread, location of message within thread, author (student vs. educator), subject line clarity, time of posting, response time from previous message, number of times message was read, number of words, primary purpose, message quality, difficulty level of topic, knowledge level, processing level and use of external resources. These variables proved to be effective in assessing 12 key areas of discussion board use. It is argued that this kind of metric is essential if we wish to advance our understanding of online discussion boards for both educators and researchers.

Overview

The use of online discussion boards has grown extensively in the past 5 years (Cooper, 2001). While this tool is viewed as revolutionary by some researchers (Hara, Bonk & Angeli, 1998; Li, 2003), others argue that our understanding of how to use online discussion in an effective and meaningful way is limited (Blignaut & Trollip, 2003).

Acquiring more cohesive and useful information on the use of discussion boards is partially dependent on developing a consistent, comprehensive, theory-driven metric to assess quality and effectiveness. Considerable research has been carried out on the use of online discussion (eg, Aviv, Erlich, Ravid & Geva, 2003; Benigno & Trentin, 2000; Berge & Muilenburg, 2000; Blignaut & Trollip, 2003; Burstall, 2000; Hara *et al*, 1998; Henri, 1992; Im & Lee, 2003–04; Love, 2002; Mazzolini & Maddison, 2003; Meyer,

2003; Roblyer & Wiencke, 2003; Rourke & Anderson, 2002; Wickstrom, 2003); however, methodological differences in assessment make it difficult to combine the results into a cohesive base of knowledge that can guide practice and education. In addition, many studies have looked at only one or two specific aspects of online discussion in detail. Several researchers attempted more complete and detailed analyses (eg, Aviv *et al*, 2003; Benigno & Trentin, 2000; Edelstein & Edwards, 2002; Hara *et al*; Im & Lee, 2003–04; Meyer, 2003; Roblyer & Wiencke, 2003; Zhu, 1998), although the scope was still somewhat limited with respect to the full range of factors that could influence successful performance.

It is argued that a more comprehensive, theory-driven assessment tool is needed to advance our understanding of how to best use discussion boards in education. The purpose of this study, then, was to research, develop and test a multicomponent, theoretically driven metric to assess the effectiveness of online discussion boards.

Literature review—developing a metric
A literature review of discussion boards and cognitive theory revealed 12 promising areas for evaluating discussion boards: social learning, cognitive processing, quality of discussion, the initial question in a thread, role of educator, navigation issues, challenges for students, types of users, attitude towards online discussion, response time, learning outside of school and learning performance. Each area is discussed below.

Social learning
Vygotsky (1978) was a pioneer in exploring the role of language in thought. He noted that conceptual learning was a collaborative effort requiring supportive dialogue. Slavin (1995) added that extensive research supports the positive effects of cooperative learning on achievement. It is reasonable, then, to expect that online discussion has the potential to support collaboration and concept development. A number of studies, however, have reported that true social interaction leading to cognitive development and resolution to actual problems addressed in discussion boards is rare (eg, Berge & Muilenburg, 2000; Biesenbach-Lucas, 2003; Garrison, Anderson & Archer, 2001; Hara *et al*, 1998; Meyer, 2003; Son, 2002; Wickstrom, 2003). Other researchers have observed significant social interaction leading to effective knowledge building (eg, Aviv *et al*, 2003; Fauske & Wade, 2003–04; Garrison *et al*, 2001; Grady, 2003; Poole, 2000; Rourke & Anderson, 2002; Schallert, Reed & D-Team, 2003). A possible resolution to this debate might lie in user acceptance of the medium, the amount of structure used to guide the discussion board and the quality of measures used to assess social interaction. There is some evidence to suggest that well-structured, focused, course-relevant questions lead to more effective discussion (eg, Aviv *et al*; Ferdig & Roehler, 2003–04; Greenlaw & DeLoach, 2003; Roblyer & Wiencke, 2003), particularly with students who embrace the online mode of interaction (eg, Biesenbach-Lucas, 2003; Ferdig & Roehler, 2003–04; Loomis, 2000; Poole, 2000; Schallert *et al*, 2003; Wu & Hiltz, 2004). Roblyer and Wiencke (2003) noted, however, that 'the lack of definition as to what constitutes observable, measurable interactive qualities [in discussion boards]... has prevented transfer from theory and research to design practice' (p. 77).

Cognitive processing

While detailed content analyses of discussion boards focusing on cognitive processing have been carried out by a number of investigators (Aviv *et al*, 2003; Berge & Muilenburg, 2000; Hara *et al*, 1998; Im & Lee, 2003–04; Knowlton & Knowlton, 2001; Roblyer & Wiencke, 2003; Rourke & Anderson, 2002; Zhu, 1998), less than half of these studies (Aviv *et al*; Berge & Muilenburg, 2000, Knowlton & Knowlton, 2001) have used theoretically based taxonomies. In addition, most assessment tools appear biased towards looking at higher-level, controversial, university-based topics. A more comprehensive metric, examining a full range of cognitive processes, would be useful in exploring a more diverse population and range of topics. The current study will use a revised version of Bloom's Taxonomy (Anderson & Krathwohl, 2001) to look at both knowledge and processing level of discussion board messages. Advantages of this revised model over the original Bloom's Taxonomy include an emphasis on actual use in planning, delivery and assessment, a focus on a broader audience (the original model was aimed at primary and junior years), and clearer descriptions of subcategories.

Quality of discussion

Aside from the level of social interaction and cognitive processing, the actual quality of an individual message has been looked at from several angles—tone (Grady, 2003; Knowlton & Knowlton, 2001), grammar (Edelstein & Edwards, 2002), number of words (eg, Biesenbach-Lucas, 2003), reasoning (Edelstein & Edwards, 2002; Love, 2002), level of controversy (Burstall, 2000) and content (Blignaut & Trollip, 2003; Edelstein & Edwards, 2002; Grady, 2003; Im & Lee, 2003–04; Merryfield, 2001). The results suggest that students need to be aware of their tone to avoid misunderstanding (Grady, 2003; Knowlton & Knowlton, 2001); messages are not always easily understood (Love, 2002); and interaction is improved with more controversial issues that do not have specific, concrete answers (Blignaut & Trollip, 2003; Burstall, 2000).

Initial question

Previous research suggests that the initial question starting off a discussion board thread is germane to the quality of subsequent interaction (Aviv *et al*, 2003; Berge & Muilenburg, 2000; Ferdig & Roehler, 2003–04; Greenlaw & DeLoach, 2003; Hara *et al*, 1998; Roblyer & Wiencke, 2003; Savage, 1998; Wickstrom, 2003). Specifically, more successful questions are clear and focused (Aviv *et al*; Berge & Muilenburg, 2000; Fauske & Wade, 2003–04; Greenlaw & DeLoach, 2003), provocative or interpretive (Greenlaw & DeLoach, 2003; Love, 2002), directly relevant to the course being taught (Aviv *et al*; Ferdig & Roehler, 2003–04; Poole, 2000), authentic (Gold, 2001), lead students towards producing specific products (Aviv *et al*; Roblyer & Wiencke, 2003) and promote higher-level thinking (Savage, 1998).

Role of educator

The role of the educator in an online discussion has received considerable attention (Berge & Muilenburg, 2000; Blignaut & Trollip, 2003; Burstall, 2000; Ferdig & Roehler, 2003–04; Figallo, 1998; Greenlaw & DeLoach, 2003; Hara *et al*, 1998; Knowlton & Knowlton, 2001; Li, 2003; Love, 2002; Mazzolini & Maddison, 2003; Moller, 1998;

Poole, 2000; Rourke & Anderson, 2002; Wickstrom, 2003), although researchers have yet to agree on the most appropriate strategy. One school of thought proposes that educators are critical to the success of an online discussion (Blignaut & Trollip, 2003; Ferdig & Roehler, 2003–04; Figallo, 1998; Greenlaw & DeLoach, 2003; Knowlton & Knowlton, 2001; Love, 2002; Moller, 1998; Roblyer & Wiencke, 2003). The educator is there to raise the level of discussion to a higher level (Figallo, 1998). Moreover, giving students the responsibility to determine the direction is not a viable approach (Moller, 1998). The other school of thought claims that educators should take a back seat and let students construct their own knowledge (Burstall, 2000; Li, 2003; Mazzolini & Maddison, 2003; Poole, 2000; Rourke & Anderson, 2002). These researchers have reported that peer messages are more effective than educator messages at stimulating a discussion and that instructor presence can actually shut a discussion down (Li, 2003; Mazzolini & Maddison, 2003; Rourke & Anderson, 2002).

Navigation issues
Students and instructors can face considerable problems trying to navigate through a typical discussion board. Specific problems observed include length of message (Hara *et al*, 1998), number of entries (Burstall, 2000; Hammond, 2000; Hara *et al*; Knowlton & Knowlton, 2001; Meyer, 2003; Ross, Kukulska-Hulme, Chappel & Joyce, 2004; Son, 2002; Wickstrom, 2003), unclear subject lines (Hara *et al*), and lack of organisation and focus (Chen & Hung, 2002; Li, 2003; Poole, 2000; Rourke & Anderson, 2002). In other words, the number and length of messages can be overwhelming, particularly if messages are not organised well. Chen and Hung (2002) add that the traditional threaded discussion format may be inadequate for true knowledge building.

Challenges for students
The challenges that students face in participating in online discussion are many—perceived inability to participate (Beaudoin, 2002; Wickstrom, 2003); reticence of many users, especially beginners, to add messages (Hammond, 2000; Mazzolini & Maddison, 2003); writing being naturally more slower than talking (Hammond, 2000); inability to change thoughts once they are written down and made public (Beaudoin, 2002; Hammond, 2000); extensive amount of time taken to participate (Loomis, 2000; Meyer, 2003; Son, 2002); lack of personal interaction (Weiss, 2000); lack of organisation and self-discipline (Schrum & Hong, 2002), misinterpretation of humor or sarcasm (Berge & Muilenburg, 2000); and the negative effect of being graded (Wickstrom, 2003). Most of these findings were observed in higher education, so it is unclear whether the secondary students examined in this study would experience the same concerns.

Types of users
There is some evidence to suggest that students assume specific and distinct roles as a discussion board evolves (Aviv *et al*, 2003; Hammond, 2000; McGrath & Hollingshead, 1994; Palloff & Pratt, 1999; Wickstrom, 2003). These roles are based on level of par-

ticipation (Beaudoin, 2002; Ferdig & Roehler, 2003–04; Greenlaw & Deloach, 2003; Hammond, 2000; Poole, 2000; Wickstrom, 2003), degree of reflection (Hara *et al*, 1998), mediation skills (Palloff & Pratt, 1999), learning style (Loomis, 2000) and number of words used (Poole, 2000). Some students who have limited writing or verbal skills may be at a distinct disadvantage (Hara *et al*). To date, there has been no systematic attempt to investigate individual differences in online discussion participants.

Attitudes towards discussion
Surprisingly little systematic research has been performed to examine student attitudes towards online discussion. A number of researchers (Hammond, 2000; Schallert *et al*, 2003; Son, 2002; Wu & Hiltz, 2004) reported that students were generally positive about using online discussion, but this conclusion was supported by anecdotal evidence only. Other researchers have observed that students tend to do the bare minimum when participation is mandatory, a possible reflection of negative attitude towards use (eg, Hara *et al*, 1998; Schallert *et al*; Wickstrom, 2003; Wu & Hiltz, 2004). Clearly more research is needed in this area.

Response time
Online dialogue differs from face-to-face conversation in several ways, but one key difference is that there are inevitable delays between posting and replying to messages within a thread. This means that students who post questions or responses may need to check repeatedly the discussion board in order to continue the conversation. Son (2002) and Yacci (2000) speculated that these delays could be a problem. A more formal analysis of response times has yet to be performed.

Learning outside of school
A large number of discussion boards are used in conjunction with face-to-face learning (eg, Hara *et al*, 1998; Love, 2002; Schrum & Hong, 2002), yet there is little research on how much discussion actually goes on outside of school environment. Schallert *et al* (2003) reported that log-on time was important—students who logged on late made few comments and received few responses from others. To date, no research has looked at the ratio of messages posted at home versus those posted during school hours. The assumption may be that students are spending time reflecting and posting messages at home, yet there are no data to support this supposition.

Learning performance
Several researchers (Chen & Hung, 2002; Fabos & Young, 1999) have challenged the conjecture that mere participation in an online discussion board guarantees the social construction of knowledge and personal understanding. One way of examining the impact of participation is to correlate it with actual learning performance. A number of studies have evaluated the effect of online discussion use by assessing self-perception of learning (eg, Hiltz, Coppola, Rotter, Turoff & Benbunan-Fich, 2000; Schallert *et al*, 2003; Swan, 2002). Only one study reported a significant increase in actual learning performance (grades) as a result of participating in online discussions. It is critical to continue testing the fundamental relationship between participation and learning.

Current study

After a thorough review of assessment methods used to evaluate discussion boards, a multicomponent metric, comprising 12 key areas, was created, and it included social learning, cognitive processing, quality of discussion, initial question, role of educator, navigation, challenges for students, types of users, attitudes towards discussion, response time, learning outside of school and learning performance. The purpose of this study was to test the effectiveness of this metric in evaluating the impact of discussion board use on learning.

Method

Sample

The sample tested consisted of 45 secondary school students enrolled in an introductory computer science course at a secondary school in a metropolitan area. The students, all males, ranging in age from 13 to 15 years old, were divided into two classes consisting of 22 and 23 students. The assignment of students to a particular class was based solely on their schedule at the beginning of the year. The data were collected and analysed a year after the students finished the course.

Procedure

The students were asked to contribute messages in two consecutive asynchronous online discussions used to supplement the learning of hypertext markup language (HTML) (24 days) and beginning programming (36 days). The online discussions were part of a regular face-to-face course that met every other day for 90 minutes. Participation in the online discussion was worth 10% of the final grade. Specific grading guidelines were not provided in order to encourage as much participation as possible. It was emphasised that messages consisting of questions or answers would be given equal weighting. It is worth noting that the majority of discussion board research is based on courses where participation is graded (eg, Burstall, 2000; Hara *et al*, 1998; Li, 2003; Love, 2002; Mazzolini & Maddison, 2003; Schrum & Hong, 2002; Son, 2002; Wickstrom, 2003). The discussion board was intended to be student-led, and the teacher would only intervene if there were problems that students could not resolve. After each of the course topics was completed (HTML first, programming last), the students were asked to fill in a survey consisting of two open-ended questions.

Data collection and analysis

Three sources of data collection were used in order to analyse all of the key components identified in the literature review. These included (1) coding the online discussion board messages, (2) analysing the statistics accumulated by the discussion board software (Blackboard 5.0) on actual use and (3) distributing attitude surveys at the end of each topic. Finally, where possible, two or more variables were used to evaluate specific components in order to improve accuracy and validity.

After an extensive review of the literature, 12 key areas of analysis were identified as promising for assessing online discussion use. The specific variables used to evaluate these areas, along with supporting references, are provided in Appendix A.

Coding of online discussion board messages
In order to make the coding scheme as transparent as possible, Appendix B provides a detailed rubric for the key variables used this study.

Blackboard statistics
The Blackboard programme automatically collected the following statistics: time when message was posted, number of times a message was read by others, number of visits an individual student made to the discussion board, number of days an individual student visited the discussion board and total number of posts an individual student made.

Survey data
Two key questions were asked of students after they completed each course topic:

1. Did you use the discussion board? Please explain in detail why or why not.
2. Was the discussion board useful to you? Explain in detail why or why not.

The responses from students were examined to identify and categorise (1) reasons for/ for not participating and (2) why the discussion board was thought to be useful or not. The frequencies of each category were then calculated.

Learning performance
An external measure of learning performance (grades for term project and term test) was used to evaluate the overall effectiveness of participating in discussion boards. The final term project grade and final exam score were correlated with the total number of visits a student made to the discussion board, total number of days that a student visited the discussion board and the total number of messages posted.

Results
Overview
Overall, a total of 260 messages were posted for both HTML and programming. The mean length of a discussion thread was of 3.5 messages ($SD = 2.3$, range 1–11 messages), and the average number of words was 48.3 ($SD = 46.2$, range 1–263 words). The subject lines were moderately clear ($M = 1.68$, $SD = 0.9$; scale range 0–3), and the quality of messages was fair to good ($M = 2.3$, $SD = 0.9$; scale range 0–4). A typical message was read an average of 29.5 times ($SD = 11.3$, range 2–77). The average time to respond to a posted message was 3630 minutes or 2.5 days ($SD = 7377$ minutes, range 1–49 109 minutes).

With respect to content, a majority of the messages were either course related or went beyond the material covered in class ($n = 223$, 86%). The primary purpose of most messages was to ask a question ($n = 63$, 24%) or to offer an answer ($n = 175$, 73%). The discussion board was rarely used for nonacademic purposes ($n = 15$, 6%).

Social learning
The number of discussion threads containing five or more messages was 26/55 or 47%. The mean number of times a typical message was read was 29.5 ($SD = 11.3$) and ranged from 2 to 77 times. Specific responses to other students in the form of questions or answers occurred in 66% of all message posted ($n = 172$). Finally, the students participated in the same discussion thread two or more times in 13 out of 28 HTML discussion threads (46%) and in 10 out of 35 programming discussion threads (29%).

Cognitive processing
According the Bloom's revised taxonomy, the predominant knowledge type demonstrated was procedural ($n = 140$, 57%) followed by conceptual ($n = 51$, 21%) and factual ($n = 50$, 21%). Metacognitive knowledge was present in only 3 out of 244 messages evaluated. With respect to processing level, the students displayed understanding most ($n = 85$, 35%) followed by remembering ($n = 66$, 27%), applying ($n = 52$, 22%), analyzing ($n = 31$, 13%) and evaluating ($n = 10$, 4%). The creative use of knowledge was observed only once.

Quality of discussion
A majority of the messages were clear ($n = 174$, 67%) or somewhat clear ($n = 70$, 27%). Only 16 messages (6%) were unclear. The message quality was good or excellent 41% of the time, fair 47% of the time and poor or incorrect 12% of the time. New knowledge was added either indirectly ($n = 69$, 27%) or directly ($n = 103$, 40%) in the majority of messages posted.

The content of the messages focused mostly on material beyond ($n = 145$, 56%) or directly related to the curriculum ($n = 78$, 30%). Nonacademic ($n = 24$, 9%) and administrative issues ($n = 6$, 2%) were discussed infrequently. Finally, the discussion threads, as a whole, were resolved (ie, questions were answered correctly) or went above and beyond the original topic 71% ($n = 100$) of the time.

Initial question
The impact of the initial question in a discussion thread was assessed by looking at two dependent variables (number of times a message was read and the length of the discussion) for five independent variables (whether the question was easily answered elsewhere, subject line clarity, message quality, knowledge type and processing level) Ten one-way ANOVAs revealed no significant differences. In other words, there appeared to be no distinct quality in an initial question that caused students to read or post more questions.

Role of educator
The philosophy of the teacher in this course was to allow the students the opportunity to construct their own knowledge. Therefore, it is not surprising that the students initiated questions in 95% ($n = 50$) of the discussion threads started. The students also ended discussions majority of the time ($n = 49$, 89%).

Overall, there were no significant differences between teacher and student messages with respect to the number of times each were read, length of the message and response time (how fast a message received a response).

Navigation
Navigation issues were examined by looking at the effect of subject line clarity and location of message within a thread (message number) on how many messages were read (reading rate) and how fast a message received a response (response time) The clarity of a subject line was not significantly related to reading rate or response time. However, the message number was significantly and negatively correlated with the average number of times the message was read ($r = -0.26$, $p < 0.001$). There was a steady drop in the average number of times a message was read from the initial message ($M = 39.18$) to the message number 11 ($M = 14.5$). The message number was not significantly related to how fast the students responded to messages (response time).

From the post-task survey data, navigation was reported as the number one problem in using the discussion board in both the HTML and programming topics ($n = 35$, 54%). Specific concerns included the following: (1) it was hard to find specific content, because there were too many messages; (2) too much clicking was involved in negotiating messages; (3) the discussion board was being diluted with messages, because the students were being graded and (4) there should be greater division and classification of topics to decrease navigation time.

Challenges for students
Aside from navigation difficulties, some students had technical or software problems ($n = 16/65$, 25%), difficulty trusting the quality of their peers' messages ($n = 14/65$, 22%) and felt inhibited by the use of grades to motivate participation ($n = 7/65$, 11%).

The students reported a variety of reasons for not using the discussion board including using other methods (using a book, searching the Internet, asking a friend) that were perceived as being faster or more efficient ($n = 25/65$, 38%), differences in learning style ($n = 8/65$, 12%), lack of ability ($n = 8/65$, 12%), forgetting to post ($n = 5/65$, 8%) and not having enough time ($n = 4/65$, 6%).

Types of users
Individual differences observed among active participants (those students who posted five or more messages) were observed with respect to the average number of messages read ($p < 0.001$), average response time ($p < 0.001$), number of words used ($p < 0.001$) and message quality ($p < 0.001$). The students also differed with respect to the number of messages that they posted ranging from 1 to 17. The students did not differ significantly with respect to clarity of subject line, difficulty of questions they responded to, knowledge type and processing level.

In the post-task survey, several students ($n = 8/65$, 12%) reported that they did not participate regularly in the discussion board, because it did not match their individual

learning style. Some students preferred to use a book—others favored looking up answers on the Internet or simply asking another student. One student learning HTML summed up this issue with the following comment:

I did not use [the] discussion board because I [felt] that it [was] easier to look up the answers to your own questions rather than rely and wait on someone else to answer them. If you just look up your question on the internet, you have an unlimited supply of information at your disposal and you can extract the amount or sections that apply to you. You also can access them at your own time, at your own pace. In addition, if you are on a roll of good solid work, it is difficult to break away, go to Blackboard, post, and then wait for the answer to continue working. If I were to just wait for answers, I do not think I would get much done if I set myself a certain amount of time for this subject.

On the other hand, a few students noted that it was easier for them to use the discussion board for more course-specific or idiosyncratic questions, because books or the Internet offered information that was too general.

Attitudes towards discussion
The measure of attitude in this study is based on the perceived usefulness of the discussion board. In the post-task survey, over one third of the students thought that the discussion board was an effective learning tool ($n = 24/65$, 37%). With respect to actual use, 38% of the students used the discussion board frequently, 25% occasionally and 27% not at all. Almost two thirds (65%) of the students reported that they had received useful information, while one third (39%) thought that they had provided helpful information to others. Eighty-two percent of the students did not indicate grade as a key motivator for participating in the discussion board.

Response time
The average time taken to respond to a message was 3630 minutes or two and a half days ($SD = 7338$ minutes). The students responded as quickly as 1 minute and as slowly as 34 days. After eliminating outliers (eg, response times greater than 10 000 minutes or 1 week, $n = 22$ messages), the average response time was 1519 minutes or about 1 day ($SD = 2204$ minutes). The response time appears to jump after the third message, from 1182 (19.7 hours) to 1853 minutes (31 hours) for the fourth message, although the sample is too small to assess statistical significance reliably.

The response time was significantly and negatively correlated with the number of times a message is read ($r = -0.254$, $p < 0.01$). In other words, the longer it took for someone to post a reply, the less likely it was that the new message would be read.

Learning outside of school
Just over half ($n = 142$, 55%) of all messages posted on the discussion board were completed outside of school hours. There were no significant differences between school and home messages with respect to clarity of subject line, message quality, response, time and number of words; however, message topics discussed at home were rated as more difficult to answer than those posted in school ($p < 0.05$).

Table 1: *Correlations among discussion board participation and learning performance measures*

	HTML final project	*HTML final test*	*Programming final project*	*Programming final test*
Number of visits	$r = 0.27$ (n.s.)	$r = 0.44$ ($p < 0.01$)	$r = 0.33$ ($p < 0.05$)	$r = 0.38$ ($p < 0.05$)
Number of days visited	$r = 0.42$ ($p < 0.01$)	$r = 0.48$ ($p < 0.01$)	$r = 0.36$ ($p < 0.05$)	$r = 0.36$ ($p < 0.05$)
Number of posts	$r = 0.31$ ($p < 0.05$)	$r = 0.44$ ($p < 0.01$)	$r = 0.33$ ($p < 0.05$)	$r = 0.35$ ($p < 0.05$)

Note: n.s., not significant; HTML, hypertext markup language.

Performance and discussion board participation
The learning performance for both HTML and beginning programming topics was positively correlated with the number of visits, number of days visited and number of messages posted with one exception—the number of visits the HTML discussion board was not significantly correlated to the final web page project grade (see Table 1).

The results above are supported by the post-task survey where almost two-thirds of the students reported learning significant concepts using the discussion board.

Discussion
The 12 areas used to assess the effectiveness of discussion boards presented useful data for both educators and researchers.

Social learning, cognitive processing and learning performance
Tracking the number of threads exceeding five messages, the purpose of a message and the number of times a student participated in the same discussion thread provided concrete evidence to suggest that students were genuinely engaged in social activity. However, social 'activity' does not necessarily guarantee that social 'learning' is taking place (eg, Berge & Muilenburg, 2000; Hara *et al*, 1998; Son, 2002; Wickstrom, 2003). The additional analysis of discussion board messages in terms of cognitive processing provided evidence that students were actively and cooperatively trying to understand and apply new concepts. Furthermore, the fact that more than two-thirds of all discussion threads were resolved or went beyond what was originally asked shows that a number of problems were being solved. Finally, correlating discussion board participation and actual performance in the course indicated that significant learning was occurring at some level. In short, this combination of assessment variables was effective in describing the level of social learning that occurred.

Quality of discussion
Examining the quality of discussion provided new and nontrivial information to the discussion board knowledge base. Past research on higher education has suggested that

if discussion boards were to be successful, there had to be controversial and thought-provoking topics to promote higher-level thinking and active discussion (eg, Blignaut & Trollip, 2003; Burstall, 2000). The results of this study suggest that there may be another role for discussion boards, one that supports more application-focused, concrete dialogue. The students learning HTML and beginning programming were able to post and answer meaningful factual, conceptual and application-based knowledge problems leading to improved learning performance. The students also posted relatively clear and unambiguous messages, a finding that was not observed by Knowlton and Knowlton (2001) or Love (2002).

It should be noted that this positive result is consistent with a number of studies in higher education, which suggest that discussion board success is significantly related to focusing on meaningful, authentic and course-related learning tasks or topics (Aviv *et al*, 2003; Ferdig & Roehler, 2003–04; Gold, 2001; Poole, 2000; Roblyer & Wiencke, 2003).

Initial question

A detailed analysis of the initial question starting off a discussion thread, based on subject line clarity, difficulty of the topic addressed, message quality and level of cognitive processing, revealed no significant differences with respect to how often messages were read or the length of the discussion. It appears for the topics looked at in this study (HTML and programming) and the type of students (secondary level) that there are no distinct characteristics of the initial question that encourage more participation. This finding is inconsistent with past research (Aviv *et al*, 2003; Berge & Muilenburg, 2000; Ferdig & Roehler, 2003–04; Greenlaw & DeLoach, 2003; Hara *et al*, 1998; Roblyer & Wiencke, 2003; Savage, 1998; Wickstrom, 2003), although it is somewhat difficult to compare given the difference in topics addressed, the educational level of students participating and the absence of commonly defined assessment tools.

Role of educator

The teacher in this study did not dominate or excessively stimulate discussion. The students initiated and ended the vast majority of discussion threads. This approach is consistent with the 'guide on the side' philosophy advocated by Burstall (2000), Li (2003), and Mazzolini and Maddison (2003). The students were not only successful at interacting and building new knowledge, but their participation contributed to better performance on final projects and tests. This result does not preclude the possibility that they could have performed even better if the teacher had taken a more active role. It does indicate, however, that students are capable of taking responsibility for a discussion and learning new facts, concepts and applications without significant teacher intervention and participation.

Because much of the knowledge covered in the discussion board went beyond the standard curriculum, and students posted messages outside of class more than 50% of the time, the online discussion board has the potential to be a powerful supplement to a traditional classroom format. The effectiveness of students in guiding the discussion

in this study is also significant for educators who have noted the extensive time drain that online discussion requires (eg, Berge & Muilenburg, 2000; Rourke & Anderson, 2002).

Navigation

Navigation issues were reported by students as the number one impediment to using the discussion board. Somewhat surprisingly, subject line clarity, which is the only initial guide to directing users in an online discussion board, was not significantly correlated with whether a message was read or how fast the message was responded to. However, messages at the end of long discussion threads were read less. This latter finding supports the claim that the large number of entries in a discussion thread can inhibit active participation.

The reading rate dropped sharply after the third message and then declined at a steady rate. Two critical questions that still need to be answered are: how many messages are users willing to read within a specific discussion, and why do they stop reading?

Chen and Hung's (2002) speculation that the traditional online discussion format is limited with respect to supporting true and personal knowledge building was not supported by the current results. Students, in spite of the navigation issues, managed to participate regularly and learn effectively. Nonetheless, features, such as notifying the author of a message when there is a response to that message or specific prompts to encourage knowledge building, might improve learning (Chung, Severance & Chung, 2003; Scardamalia & Bereiter, 1999).

Challenges for students

Secondary students experienced some of the same challenges as their higher education counterparts: reticence to use the discussion board (over 25% of all students posted two or fewer messages), time challenges, lack of organisation and the negative effect of being graded. While the discussion board was used frequently and improved learning for many students, there are clear obstacles to using this tool.

Types of users and attitude towards use

To date, individual differences in using a discussion board have not been looked at in a comprehensive way, although anecdotal evidence suggests that students assume specific roles (eg, Hammond, 2000; McGrath & Hollingshead, 1994; Palloff & Pratt, 1999; Wickstrom, 2003). The results from the current study support previous anecdotal observations. The students in this study could be significantly differentiated based on the number of messages they read, how fast they responded to the messages, number of words they wrote and the overall quality of their messages. These measures, when viewed as a whole, could be seen as a reflection of general enthusiasm for using discussion boards. In other words, students who read messages more, respond to messages quickly and write detailed, high-quality messages could reasonably be considered as enthusiastic participants. Not reading or responding to messages or providing short, one-sentence messages might be a reflection of apathy. Lack of response could also mean

fear of committing a message to a public forum (Beaudoin, 2002) or an inability to understand what is going on in a discussion (Ferdig & Roehler, 2003–04).

The results for identifying the distinct qualities of discussion board users were consistent with students' attitudes towards use. Roughly one third of all students said that they used the discussion board sparingly or not at all. They noted that either the discussion board did not match their personal style of learning or that there were more efficient ways for them to learn (eg, using a book, talking with someone, using the Internet). Another third of all students appeared to have a somewhat indifferent attitude and used discussion boards on occasion. The final third were enthusiastic participants who received and offered new ideas frequently.

These differences in use and attitude should be noted by educators. While some students may thrive with this tool, others need more convincing or may not be prepared to use the discussion board at all.

Response time
While response time has not been formally examined previously, the results of this study support Son's (2002) and Yacci's (2000) speculation that delays in responding to messages could have a negative impact. The students responded relatively quickly to the first three messages, after which the response time jumped by over 50%. When you consider the significant and negative correlation between the response and number of times a message is read, the response time becomes even more critical. In other words, there appears to be a window of opportunity, roughly 19 hours, in which students will follow up on a discussion board message, after which they start to lose interest. This result is supported by research noting that the optimum response time for an instructor should be 24 hours or less (Roblyer & Wiencke, 2003).

Delays in response time may be unavoidable with a traditional discussion board format, which is relatively flat and serial. Chen and Hung (2002) proposed a new feature where students have the ability to electronically indicate interest in a specific message or topic and then are automatically informed of any future messages linked to their interests. This kind of tool has the potential to increase the real time feel of a face-to-face discussion. It could also reduce the time spent checking for a response to one's message. It is worthwhile to note that without some sort of automatic notification system, some students will post messages a week and even a month after an original discussion is started and that these messages will be rarely read.

Learning outside of school
The discussion board in this study was used as a supplement to teaching a secondary course in HTML and programming, and the students were willing to use it outside of school hours. This result is particularly noteworthy given that (1) a majority of the topics covered in the discussion board went beyond the curriculum; (2) more difficult

topics were discussed at home; and (3) the use of the discussion board was significantly correlated with learning performance.

Successful, meaningful and effective use of discussion boards outside of school hours could prove to be beneficial to educators. In large classes, it is often not possible to answer the range and number of questions during class (Ferdig & Roehler, 2003–04). The use of discussion boards can clearly augment the traditional in-class model of learning.

Limitations of the study
While it is argued that the metric used in this study is multidimensional and supported by solid cognitive theory and extensive literature review, the specific results reported are limited for several reasons.

First, the sample size was relatively small, consisting of only males. Second, the context of learning was narrowly defined, focusing on the learning of a technical, procedure-based subject, namely computer programming. Third, online discussion acted as a supplement to a traditional face-to-face course. Therefore, in order to firmly establish the effectiveness of the metric presented in this study, more research needs to be done on larger, more diverse populations, in a broader range of subjects, looking at stand alone as well as supplemental use of online discussion.

Summary
The assessment tool developed in this study proved to be useful in evaluating key elements of online discussion use. The power of the metric rests in the wide range of variables assessed based on a firm theoretical base. The highly selective and somewhat idiosyncratic nature of previous discussion board metrics makes it difficult to compare and fully evaluate results. The metric in this study uncovered valuable information about asynchronous learning including the degree of social interaction and learning that occurred, level of cognitive processing, quality of the discussion, effect of the initial question, role of educator, challenges that participants experience while using a discussion board, types of users, attitude towards discussion, effect of responding too slowly to messages, impact of learning outside of school and effect of discussion boards on learning performance. However, the metric needs to be further tested in a wider variety of contexts with a larger, more diverse population.

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Appendix A: Variables used to analyse discussion board message

Area	Variables used	Data source	Reference
Social learning	Number of threads with more than five messages	DB	Mazzolini & Maddison (2003)
	Average number of messages read	DB	None
	Purpose of message (open question, specific question, answers, independent comment, not academic)	DB	Aviv *et al* (2003); Blignaut & Trollip (2003); Garrison *et al* (2001); Henri (1992); Meyer (2003); Son (2002); Zhu (1998)
	Number of times a student posts two or more messages in the same discussion thread	DB	Aviv *et al* (2003); Hammond (2000); Roblyer & Wiencke (2003); Wickstrom (2003)
Cognitive processing	Knowledge type (facts, concepts, procedures, metacognitive knowledge)	DB	Anderson & Krathwohl (2001); Aviv *et al* (2003); Hara *et al* (1998); Henri (1992)
	Processing level (remember, understand, apply, analyse, evaluate)	DB	Anderson & Krathwohl (2001); Aviv *et al* (2003); Hara *et al* (1998); Henri (1992); Poole (2000)
Quality of discussion	Message clarity (unclear, somewhat clear, clear)	DB	None
	Message quality (poor, fair, good, excellent)	DB	Love (2002)
	Presence of newknowledge (no, yes-unrelated to question, yes-related to question)	DB	Vygotsky (1978); Berge & Muilenburg (2000); Hara *et al* (1998);
	Course knowledge in message (none, administrative, course related, beyond course curriculum, highly advanced)	DB	Grady (2003); Hara *et al* (1998); Love (2002); Son (2002)

Area	Variables used	Data source	Reference
	External resources used (none, teacher, another message, computer programme, web, book)	DB	Ferdig & Roehler (2003–04); Im & Lee (2003–04); Love (2002)
	Resolution of discussion (unresolved, partially resolved, resolved, resolved beyond what was asked)	DB	Garrison *et al* (2001); Slavin (1995); Vygotsky (1978)
Initial question	Easily answered with other source (no, maybe, yes)	DB	Berge & Muilenburg (2000); Garrison *et al* (2001); Hara *et al* (1998); Savage (1998); Wickstrom (2003)
	Subject line clarity (unclear, somewhat clear, pretty clear, very clear)	DB	Hara *et al* (1998)
	Message quality (poor, fair, good, excellent)	DB	Aviv *et al* (2003); Love (2002)
	Knowledge type (facts, concepts, procedures, metacognitive knowledge)	DB	Anderson & Krathwohl (2001); Aviv *et al* (2003); Hara *et al* (1998); Henri (1992)
	Processing level (remember, understand, apply, analyse, evaluate)	DB	Anderson & Krathwohl (2001); Aviv *et al* (2003); Hara *et al* (1998); Henri (1992); Meyer (2003)
Role of educator	Compare student vs. teacher messages based on the following characteristics:		
	% of total threads started % of total threads ended	DB	Blignaut & Trollip (2003); Burstall (2000); Hara *et al* (1998); Knowlton & Knowlton (2001); Mazzolini & Maddison (2003)
	Number of times messages were read	BB stats	None
	Length of message	Word count	Biesenbach-Lucas (2003); Hara *et al* (1998); Poole (2000)
	Response time (how long it takes for someone to respond to posted message)	BB stats	Hammond (2000); Hara *et al* (1998); Yacci (2000)
Navigation issues	Reasons given for using/not using discussion board	Survey	Burstall (2000); Hara *et al* (1998); Hammond (2000)

Area	Variables used	Data source	Reference
	Subject line clarity (unclear, somewhat clear, pretty clear, very clear) correlated with how often a message was read (reading rate) and how long it took to respond to a message (response time)	DB and BB stats	Hara *et al* (1998)
Challenges for students	Challenges identified in open-ended survey questions	Survey	Burstall (2000); Hara *et al* (1998); Hammond (2000); Knowlton & Knowlton (2001); Son (2002); Wickstrom (2003)
Type of user	Participants were compared to each other on ALL variables assessed in the study, except those based on survey questions	DB and BB stats	Aviv *et al* (2003); Hammond (2000); McGrath & Hollingshead (1994); Palloff & Pratt (1999); Wickstrom (2003)
Attitude towards discussion	Explanation of why discussion board was/ was not useful in survey questions	Survey	Burstall (2000); Hara *et al* (1998); Hammond (2000); Schallert *et al* (2003)
Response time	Time taken to respond to a posted message	BB stats	Hammond (2000); Hara *et al* (1998); Yacci (2000)
Learning location	Compare inside school hours (9 a.m. until 3:30 p.m.) vs. outside school hours on the following variables: Subject line clarity (unclear, somewhat clear, pretty clear, very clear) correlated with reading rate and response time Message quality (poor, fair, good, excellent) Response time (How long it takes for someone to respond to posted message) Length of message Easily answered with other source (no, maybe, yes)	BB stats	None

Area	Variables used	Data source	Reference
Learning performance	Correlation of final test score with total number of visits, number of days visited and number of messages posted Correlation of final project grade with total number of visits, number of days visited and number of messages posted	BB stats	Beaudoin (2002); Hiltz *et al* (2000); Wu & Hiltz (2004)

Appendix B: Detailed rubric for assessing online discussion data

Variable	Rating	Criteria
Subject line clarity	0—Unclear	Confusing or cryptic subject line—often only one or two words
	1—Somewhat clear	Subject line is vague but does capture the general but not the specific topic area
	2—Pretty clear	You have a good idea what the specific topic is based on the subject line; however, the exact nature of the message content is not completely evident
	3—Very clear	The subject line matches exactly what the message is about
Question easily answered from other sources	0—No	Question is asked that is idiosyncratic or very challenging and requires social interaction (eg, course or assignment-specific question)
	1—Maybe	If a student were resourceful, he might be able to find an answer to the question using another source (eg, searching the web, consulting a book)
	2—Yes	Question can be easily answered without the discussion board (eg, given in handout or course web page)
Posting time (learning location)	1—In school	Message posted from 9:00 a.m. to 3:30 p.m.
	2—Outside school	Message posted from 3:31 a.m. to 8:59 p.m.
Response time	Minutes	Difference between the time a message is posted and the time the following message is posted
Number of times read		Blackboard calculates and posts the number of times each message is read
Primary purpose of a message	1—Open	Open question directed at the class
	2—Specific	Specific question asked of a student in the discussion
	3—Reply	Reply to a question asked
	4—Independent	Independent comment made that is not related to the topic being discussed in a thread

Variable	Rating	Criteria
	5—Nonacademic	A comment made that is not course related and adds no educational value
Message clarity	0—Unclear	Message is unclear or confusing—it is typically followed by a message asking for clarification
	1—Somewhat clear	Message is somewhat clear, but there are still confusing or vague points that need clarification
	2—Clear	The message is clear and appears to be understood by the participants in the discussion thread
New knowledge added	1—No	No new knowledge was added in a message
	2—Yes (indirectly)	New knowledge was added but was not related to the initial question or discussion topic OR a question is asked that implies that something new can be done
	3—Yes (directly)	New knowledge added that is directly related to the discussion thread topic
Message quality	0—Incorrect	Incorrect information is provided
	1—Poor	Information provided is unrelated to the discussion thread or course OR a question asked is confusing and hard to follow
	2—Fair	Information provided answers one aspect of question with a thread, but not whole question OR a question is asked out of context of the thread
	3—Good	Information is provided that answers most or all parts of question within a thread OR a relevant and clear question is asked
	4—Excellent	Information provides clear and complete response to a question asked and ADDS additional and relevant details OR insightful question is asked on an advanced topic (one that goes beyond the course curriculum) often promoting considerable dialogue and/or debate
Course knowledge	1—None	No knowledge is provided (eg, social comment)
	2—Unrelated	Knowledge is provided that is unrelated to the course
	3—Administrative	Administrative knowledge (eg, due dates or the requirements for the final project)
	4—Course	Knowledge is provided that supports the course curriculum
	5—Beyond course	Knowledge is provided that goes beyond the course curriculum
	6—Very advanced	Knowledge that goes well beyond the course curriculum—usually only a few students can understand

Variable	Rating	Criteria
Knowledge type	1—Fact	Student offers an isolated fact (eg, location of a website, syntax of a specific command, code for a colour)
	2—Concept	Student presents two or more connected facts (eg, connecting facts with conjunctive adverbs like because, consequently, therefore, otherwise)
	3—Procedure	Student provides information on how to achieve a specific task
	4—Metacognitive	Student is reflecting about a strategy to solve a problem task or emotional state while learning
Processing level	0—Clarification	Student is asking what a question or comment means—often referring to a specific element or fact in a problem
	1—Remember	Evidence that student is recalling or trying to recall a fact, concept or procedure
	2—Understand	The student understands or is trying to understand a concept or a procedure
	3—Apply	A student is applying or trying knowledge which typically involves the use of a procedure
	4—Analyse	A student is actively making connections between two or more concepts
	5—Evaluate	Student provides comments about effectiveness of a procedure or approach to solving a problem
External resources used	1—None/unknown	No clear resources are noted or evident
	2—Teacher/course information	Reference is made to the teacher or course information in a message
	3—Another message	Information from another posted message is referenced
	4—Programming or HTML code	Reference is made to specific HTML or programming code
	5—Web	A website is referenced
	6—Book	Reference is made to the course textbook
Resolution of discussion thread	1—Unresolved	Information was not given to solve the question(s) raised in the thread
	2—Partially resolved	Information is offered that partially answers the question (s) being asked in the thread
	3—Resolved	Complete and correct information is provided to resolve the questions being asked in the thread
	4—Resolved beyond what was asked	Information offered that answers and goes beyond the question being asked in the thread