Australian Journal of Educational & Developmental Psychology Vol. 5, 2005, pp 117-127

Analysis of Asynchronous Online Discussion using the SOLO Taxonomy

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ABSTRACT

The online learning environment provides the opportunity for remote groups of students to interact with instructors and each other. Most web based learning platforms facilitate asynchronous online discussions between participants. These discussion forums are designed to replicate the face to face tutorial setting and provide a medium for the expression and development of student ideas. In this paper, an online discussion between twenty-eight teachers retraining in the field of mathematics will be analysed using the SOLO taxonomy. The analysis will focus on the capacity of web based learning environments to foster deep learning through the careful design of discussion tasks.

Keywords: asynchronous communication; SOLO Taxonomy; online learning

INTRODUCTION

In recent years the prevalence of constructivist and postmodern theories of learning have led to widespread acceptance of the need for teaching methods that promote the development of a 'shared understanding' of knowledge (McDonald, 2002). The use of discussion as a teaching strategy is one way of developing knowledge in a collective environment (Killen, 2003). The current growth in higher education online courses has seen a dramatic increase in the number of students interacting in 'virtual space' through the use of web based learning platforms. Online discussion boards are now widely used teaching tools through which students can share ideas, formulate understanding and develop social bonds with peers and instructors. The text based nature of the discussion boards present an opportunity for educational researchers to actively analyse discussion threads in order to determine if deep learning is facilitated in this new learning medium (Meyer, 2004).

Most discussion in the online environment currently takes place in an asynchronous format (Armitt, Slack, Green,& Beer, 2002) where students learning in remote locations read and make postings on virtual discussion boards at a time of their choosing. The asynchronous environment can create opportunities for learning beyond that which can occur in real time, either virtually or face to face (Koory, 2003). Poole (2000) reported evidence that students prefer time independent discussions in comparison to online synchronous exchanges, which can be difficult to manage with large groups. In addition, asynchronous discussions provide for student reflection time, rather than encouraging spontaneous responses (Lim & Tan, 2001). Im and Lee (2003) conducted a comparative study of synchronous and asynchronous communication within a preservice teacher program. They found that while the synchronous

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interactions were useful in establishing social bonds within the group, that asynchronous discussions were more useful for task-oriented communications. Further, they found that as the course progressed, the synchronous discussions remained at the social bond formation level and did not progress to a more meaningful learning stage.

Although asynchronicity has some advantages over real time discussions, it can still be difficult to manage effectively in order to assist student learning. Inferior online discussions may result when there are poorly designed discussion topics, infrequent or non-existent instructor feedback, irrelevant or negative feedback or difficulty in maintaining discussion momentum (Whittle, Morgan & Maltby, 2000). It seems that the actions of the instructor or 'e-moderator' are pivotal in both the design of the online discussion forum and the maintenance and guidance provided throughout any discussions (Barker, 2002, Salmon, 2003). Slack, Beer, Armitt & Green (2003) found that while online discussion can facilitate deep learning, that it does not happen spontaneously, and may require careful instructor mediation and support in order to develop.

Structuring and Maintaining Online Discussions

The online discussion forum within a course can serve multiple purposes, from providing a forum for social bond formation through to facilitating the construction of new knowledge. If the discussion forum is intended to encourage deep learning, then the input of the instructor should foster that aim. While research in this field is still in its infancy, there are some common themes emerging. Most notably, the research points to the need for a carefully structured virtual learning environment (Ellis & Hafner, 2003, Salmon, 2003)

Aviv, Erlich, Ravid & Geva (2003) made a direct comparison between structured and non-structured asynchronous learning networks and found a significant statistical difference in the level of cognitive activity. Specifically, they found that the structured online learning environment resulted in a high phase of critical thinking and the development of cohesive cliques that assisted learning amongst students. Unlike traditional texts and course notes, online discussion forums tends to progress and develop in a non-linear manner, which can present the student with the difficult task of sorting through often irrelevant and disorderly postings (Winiecki, 1999, Schwan, Straub & Hesse, 2002). These problems accentuate the need for instructors to develop straightforward, comprehensible and self-explanatory discussion forums. In addition, if the structure provided necessitates the sharing of ideas, then students are more likely to actively 'talk' to each other, rather than simply post individual responses (Benfield, 2002).

There are numerous ways to encourage student interaction within online courses. Dennen (2002) likens the virtual learning environment to an empty 'pedagogical' shell waiting to be filled by students. She stresses the need for discussion tasks to have multiple answers rather than 'one clear, expected answer'(p.4). If the discursive format is to be used to its full potential then the tasks that students are attempting need to be suitably multi-dimensional so as to allow numerous perspectives and opinions. The task should have no one 'right' or obvious answer, but should allow for the sharing of different points of view in order for participants to develop a collective understanding of the complexities (Salmon, 2003).

Analysis of online discussions

The analysis of online discussion is a relatively new research topic and many techniques are being used for this purpose, depending on the research question being asked. Johnson, Bishop, Holt, Stirling & Zane (2001) used transcript analysis of online conferences to distinguish between the following types of exchanges: social communication, academic interaction, academic monologues and communication about administration issues. They found that student communication was generally dominated by academic monologues which did not make links to contributions by other students. They did find, however, that academic interaction increased in the latter part of the course.

In a similar study, Barret & Lally (1999) applied content analysis to discussion transcripts in order to distinguish between social, interactive, surface and deep cognitive skills and metacognitive knowledge and skills. They found some differences in the way that men and women interact in the online learning environment, but overall the participants appreciated the interactive nature of the online component of the course as it made them feel part of a community of learners. Im & Lee (2003) analysed both synchronous and asynchronous discussion threads according to content based on the following five categories: related to the topic, related to academic learning, related to discussion management, social interaction, technical management. They also analysed the transcripts according to three stages of development; social bond formation, information sharing and advanced stages. They found a progression toward more advanced learning, characterised by the use of metacognitive skills such as awareness, reflections and evaluation, in the asynchronous format over the period of the course.

While the studies mentioned above tried to distinguish between different types of student postings, Angeli, Valanides & Bonk (2003) included an analysis of the quality of postings from a group of preservice teachers, according to the following categories; social interaction, unsupported statements, questioning for clarification and critical thinking. They found that most responses fitted in to the first three categories with a disappointing percentage of responses fitting into the critical thinking category. They felt that the instructor's lack of interaction and moderation within the discussion threads could have contributed to the lack of higher order responses.

Meyer (2004) conducted a study using four differing frameworks to examine online discussion threads. Two developmental frameworks were implemented to measure the extent of students' reasoning skills and the extent of intellectual and ethical development. In addition, two frameworks attempted to capture 'levels of thinking'. She concluded that while the use of a number of different frameworks can help to build a multi-dimensional picture of student responses, that some frameworks (Perry, 1999) are more problematic to apply than others (King & Kitchener, 1994). In contrast to Angeli et al.(2003), Meyer found large proportions of the responses (32.5 – 54.3%) to be in the higher order/deep learning categories. It seems, as it does in conventional classrooms, that the large number of confounding factors (instructor input, discussion board design, degree of social interaction etc) in any online learning environment can be influential in determining the degree of deep learning that occurs. Indeed, analysis of discussion transcripts may provide only a small part of the solution, as we should acknowledge that some learning may occur informally and silently due to the reluctance of some learners to fully participate in the online format. (Gulati, 2004)

METHOD

The purpose of this study is to evaluate an online discussion involving a group of 28 teachers retraining as secondary teachers of mathematics. The students were undertaking a postgraduate program, including courses incorporating an integrated approach to the learning of mathematical content and current pedagogical techniques. The program had previously operated in a face-to-face learning environment and this particular cohort were the first group to embark on the retraining in the distance format. Similarly, the instructors teaching in the program were inexperienced users of the online learning platform. This detailed study of one of the online tasks was undertaken as one method of course evaluation.

Student participation in online discussion can be evaluated in a purely quantitative manner by counting the number of interactions for each student. However, such a measurement gives no indication of the quality of student responses. Biggs and Collis (1982) developed the SOLO taxonomy as a means of evaluating the quality of student learning outcomes. The taxonomy provides a consistent framework through which to evaluate student responses and has been widely used in educational research as a means of determining the complexity and depth of student learning outcomes (Hawkins & Hedberg, 1986, Chick, Watson & Collis, 1988, Chick, 1998, Tang & Watkins, 1994). According to the taxonomy, student responses can be classified according to the level of inherent complexity. Responses may be classified as prestructural, unistructural, multistructural, relational or extended abstract (Biggs & Collis, 1982).

The SOLO taxonomy has previously been used to examine discussion threads to ascertain the degree of deep learning that has occurred throughout a course (Slack, Beer, Armitt & Green, 2003). Slack et al. (2003) examined transcripts from peer to peer synchronous discussion threads and found that the SOLO taxonomy was a useful tool in determining the degree to which deep learning had occurred. Whittle et al. (2000) also used the SOLO taxonomy to analyse asynchronous discussion threads as they believe that its strength is in delineating conceptual processes.

For this study an online discussion thread was chosen due to the relatively high number of responses that it generated. The task is a representation of the classic 'Monty Hall' probability problem (Figure 1). The students were simply asked 'What do you think about the car and the goat?' As the discussion proceeded it became clear that the students were experiencing considerable cognitive conflict with regard to the task. Much dialogue was generated in their efforts to reconcile their preconceived notions with their knowledge of probability theory.

Figure 1: Probability problem

> Extract from Stein, S. (1996). *Strength in Numbers: Discovering the Joy and Power of Mathematics in Everyday Life*, John Wiley.
>
> The Car and Two Goats
> *Suppose you are on a game show, and you're given the choice of three doors. Behind one door is a car; behind the others goats. You pick a door – say Number 1 – and the host, who knows what's behind each door, opens another door – say, Number 3 – to reveal a goat. He then says to you, "Do you want to pick door Number 2?" Is it to your advantage to switch your choice?*

For this study the students were divided into two groups: full time (n=16) and part time (n=12). Two students in the part time group did not participate in the particular thread chosen for analysis and the part time students were granted a longer time period over which to complete all online tasks. The two groups did not interact with each other on the discussion board. The discussion threads were analysed using the framework of the SOLO taxonomy. Examples of student and instructor responses at each SOLO level are presented in Table 1. Each discussion posting was classified from 1 (prestructural) to 5 (extended abstract) depending on its complexity and relevance to the discussion. Social interaction postings were classified as prestructural. Two raters classified the data and the initial reliability was 88%. With further discussion, consensus was reached on the classification of all postings.

RESULTS

For the initial analysis, the student postings were classified according to the five levels of the SOLO Taxonomy (Table 2). The majority of responses (52%) to the task were classified as being at the multistructural (19.3% of postings), relational (30.1% of postings) or extended abstract (2.6% of postings) levels. However, this simplistic analysis gives no indication of how the level 3, 4 and 5 responses were distributed amongst the student population.

Table 1: SOLO Taxonomy Levels and Transcript Examples

SOLO Level	Coding Description	Transcript Examples
Prestructural (1)	The task itself is not approached in a meaningful way such as using Tautology, or just repeating the question. The student hasn't understood the point.	**Student:** I felt a bit confused before. But now the algebra has really confused me. I think I need to work through the probability section again. But nobody wins these competitions anyway. **Instructor:** Wouldn't it be nice if mathematics (and the universe in general) conformed to our way of thinking. It would certainly make learning a lot easier. Unfortunately it doesn't seem to be the case in a lot of situations.
Unistructural (2)	One relevant aspect of the task is picked up and there is no relationship between facts or ideas	**Student:** You made me realise that by swapping I would have a greater chance of winning **Instructor**: I'm wondering if you can tell me why there is a 9/10 chance of being correct if you swap rather than ½ as the car will either be behind the door you originally chose or the other door.
Multistructural (3)	Several independent aspects of the task are picked up and understood serially, but are not interrelated	**Student**: I can't see any other solution than a 50/50 for getting a car or a goat.. there are only two choices left, you have a 1 in 2 chance of getting a car or getting a goat. I think the selection of a goat in the first box is an event independent of the subsequent choice.. but I wouldn't bet my house on it. **Instructor**: I like the examples you have given. They have particular relevance if you consider diagnosis of disease – which is a probability based decision. Regarding the car and the goat. Have you done an experiment with say 10 counters and looked at the results? It would be interesting to see how it compares to ½.
Relational (4)	Relevant aspects are integrated into an overall coherent structure	**Student**: I disagree with you on the ½ probability if you switch. It's a complementary problem, so if you have a 1/3 chance of choosing the car the first time, you have a 2/3 chance of not. So when you switch it gives you a 2/3 chance of the car, even though there are only 2 doors left. The probability is still base on the initial choice of 3 doors. Think of it if you didn't switch you still have a 1/3 chance of the car that you started with, even though there are only 2 doors left. Your odds seem to have improved to ½, but your choice was based on 1/3. **Instructor**: (no postings made at this level)
Extended Abstract (5)	The coherent whole is generalized or re-conceptualized to a higher level of abstraction.	**Student**: After further thought I agree with the 2/3 chance theory. My theory just didn't add up when I applied it to really big numbers. Therefore the probability of a single event happening is 1/n where n>0 and the probability of it not occurring is (n-1)/n where n>0. Therefore regardless of how many windows are taken from the equation, the probability remains the same for the event occurring, therefore the probability for the event not occurring must remain the same. As the windows are knocked out by the host, the chosen window remains at odds of 1/n, however the odds of each remaining window increases….I have derived a more generalised formula to calculate the probability of each of the non chosen windows as the host removes windows from the equation. If n = the number of possible choices and x= the number of windows removed and R = the probability of each of the remaining windows, then R = (n-1)/(n^2-xn).[the student went on to refine this formula in further postings] **Instructor**: (no postings made at this level)

Coding descriptions from Chan, Tsui, Chan & Hong (2002)

Table 2: Student Postings classified according to SOLO taxonomy level

Solo Level	Full time group No. of student postings	Part time group No. of student postings	Total
Prestructural (1)	17	6	23 (20.2%)
Unistructural (2)	22	9	31 (27.2%)
Multistructural (3)	11	11	22 (19.3%)
Relational (4)	26	9	35 (30.1%)
Extended Abstract (5)	3	0	3 (2.6%)
Total	79	35	114

Table 3 details the SOLO taxonomy levels for the responses of individual students. The mean SOLO level for each individual's postings was calculated (omitting the prestructural responses so that only task related responses were included). In addition Table 3 includes the students' final grade in the course. It should be noted that only 10% of the final grade was dependent on student participation in the online tasks and that the task analysed for this study was only one of five tasks for the course. The remainder of the assessment included tasks related to student understanding of Stage 5 (Year 10) mathematical content and a unit planning task related to the teaching of that content. Correlation tests reveal no significant relationship between the no. of postings and a student's final grade in the course (0.165, $p = 0.421$), or between the mean SOLO level of a student's postings and the student's final grade in the course (0.202, $p = 0.303$). Likewise, there was no significant relationship between the no. of student postings and the mean SOLO level of the postings (0.040, $p = 0.845$).
Prior studies have found that the quality of student responses have generally improved over time as a course progresses (Im & Lee, 2003). For this study the discussion continued over a period of 48 days for the full time group and over a period of only 18 days for the part time group, despite the fact that the latter group could have taken more time than the former. Table 4 reveals the pattern of postings over 5 day periods for both the full and part time groups. There appears to be little evidence that the quality of responses, as determined by the SOLO taxonomy, increased over the period of either discussion. This is supported by the lack of significant correlation coefficients between the day of posting and the SOLO level (-0.177, $p = 0.118$ for the full time group; -0.148, $p = 0.396$ for the part time group). Table 4 clearly demonstrates, however, that each discussion tends to have a 'peak' time of activity. This occurs between days 11-15 for the full time group and between days 6-10 for the part time group. It would be reasonable to surmise that any input by instructors would have maximum effect during these 'peak' times.

Salmon (2003) emphasises the key role of the instructor or 'e-moderator' in the online learning process. She argues that the interactions between the instructor and participants can determine the degree of deep learning that occurs during a discussion. In this study the instructors were experienced with teaching the content of the course in a face to face setting, but were novices with regard to the online learning setting. They had few expectations for the discussion board tasks beyond that of enabling a forum for students to interact with them and each other. As the course progressed, the instructors generally took the approach of using low level comments and questioning to elicit more detailed responses from students. Table 5 reveals the lack of complexity in the postings by the instructors, particularly when compared with the student responses in Table 2.

Table 3: Full and Part time groups – Individual student postings classified according to SOLO taxonomy level

Student number	No. of Prestructural (1) responses	No. of Unistructural (2) responses	No. of Multistructural (3) responses	No. of Relational (4) responses	No. of Extended Abstract (5) responses	Mean SOLO level (omitting Prestructural postings)	Total No. of postings	Student's Final Grade in course
			Full time group					
1	3	1	0	4	0	3.6	8	53
2	2	1	1	1	0	3.0	5	67
3	0	4	1	1	0	2.5	6	61
4	1	3	0	1	0	2.5	5	68
5	0	1	0	1	0	3.0	2	66
6	0	0	1	1	0	3.5	2	86
7	0	0	1	1	0	3.5	2	77
8	1	2	2	6	0	3.4	11	89
9	1	0	1	2	0	3.7	4	75
10	3	1	1	2	0	3.3	7	71
11	4	1	1	3	3	4.0	12	88
12	0	3	1	0	0	2.3	4	79
13	1	1	0	1	0	3.0	3	70
14	0	0	1	1	0	3.5	2	73
15	0	1	0	1	0	3.0	2	76
16	1	3	0	0	0	2.0	4	51
			Part time group					
1	0	0	1	1	0	3.5	2	79
2	0	1	2	2	0	3.2	5	87
3	0	0	3	1	0	3.3	4	72
4	1	0	2	0	0	3.0	3	80
5	4	3	1	0	0	2.3	8	76
6	1	3	0	2	0	2.8	6	86
7	0	0	0	1	0	4	1	58
8	0	0	1	0	0	3	1	68
9	0	1	0	1	0	3	2	88
10	0	1	1	1	0	3.0	3	84

It is also illuminating to look at the timing of the instructor postings and the effect that prudent timing may have with regard to fostering a productive discussion. Figure 2 demonstrates that periods of high student interaction were often preceded by numerous instructor postings, which generally took the form of questions designed to encourage student reflection. It is evident, however, that once the 'peak' of a discussion has elapsed, that further instructor postings may be ineffective in promoting further discussion. At this point, however, expert instructor intervention in the form of 'e-weaving' (Salmon, 2003) could result in further student learning, reflection and discussion. The timing of instructor postings and the SOLO level of instructor postings are further revealed in Table 6. It can be seem that the higher level comments by the instructors (although it should be remembered that the highest instructor comments where only at SOLO level 3) do precede high level postings by students. For example, a level three instructor posting on day nine was followed by four level four student postings on the following day.

Table 4: Changes in the mean SOLO level over the time of the discussion

Full time group			Part time group		
Days of discussion	No. of postings (omitting prestructural postings)	Mean SOLO level of all postings (omitting prestructual postings)	Days of discussion	No. of postings (omitting prestructural postings)	Mean SOLO level of all postings (omitting prestructural postings)
1-5	2	3.0	1-5	6	3.3
6-10	15	3.3	6-10	12	2.8
11-15	24	3.4	11-15	7	3.0
16-20	9	3.0	16-18	4	3.3
21-25	4	2.0			
26-30	4	3.5			
31-35	2	2.0			
36-40	0	-			
41-45	1	2.0			
46-48	1	3.0			

Table 5: Instructor Postings classified according to SOLO taxonomy level

Solo Level	Instructor 1 postings	Instructor 2 postings	Total
Prestructural (1)	11	8	19 (36.5%)
Unistructural (2)	17	12	29 (55.8%)
Multistructural (3)	3	1	4 (7.7%)
Relational (4)	0	0	0
Extended Abstract (5)	0	0	0
Total	31	21	52

Figure 2: Discussion Postings as a Function of Time (full time group)

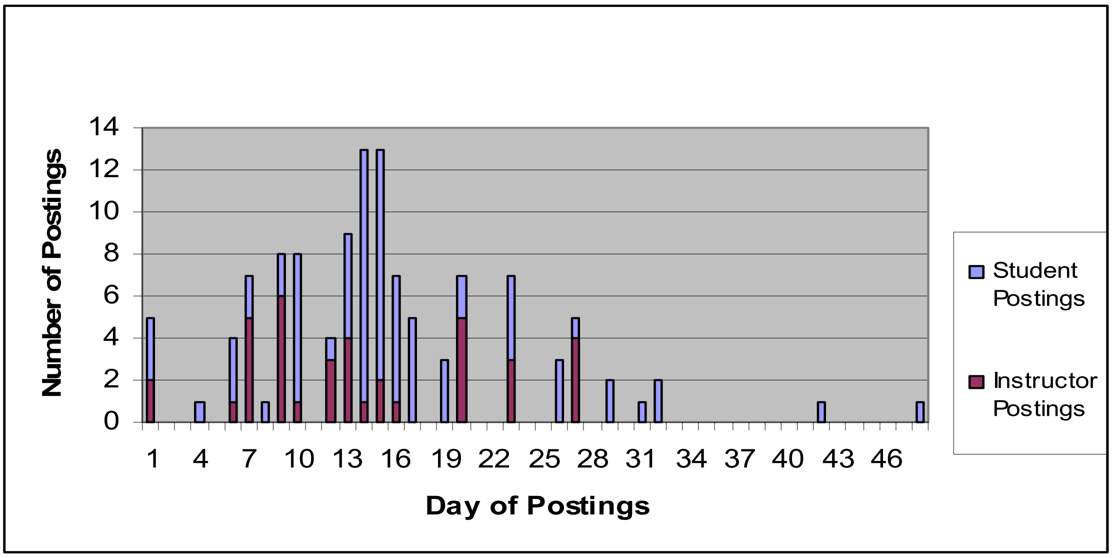

Table 6: SOLO level of Instructor postings and student postings as a function of time (full time group)

Time of posting (day)	SOLO level of Instructor postings	SOLO level of Student Postings
1	2,1	4,1,1
4		2
6	2	4,2,2
7	2,2,2,1,1	4,4
8		4
9	1,2,2,2,2,3	2,4
10		3,2,3,4,4,4,4
12	3,2,2	4
13	2,2,1,2	2,3,4,2,4
14	2	2,3,4,4,1,3,1,2,1,2,1,2,4,3
15	2,2	4,1,5,3,1,4,4,4,5,5,2
16	1	1,4,3,1,4,1
17		4,3,2,2,2
19		1,1,1
20	1,1,2,1,1	1,3
23	1,1,2	2,2,2,2
26	4,1,2	
27	4	1,1,1,1
29		1,4
31		2
32		1,2
42		2
48		3

DISCUSSION

The study has highlighted many of the complexities involved in conducting asynchronous discussions in order to create learning opportunities for students. Firstly, it is evident that for students to actively engage in a discussion, that the given task or topic should be sufficiently open-ended so as to encourage the expression of multiple viewpoints and opinions. The discussion topic chosen for examination in this paper had the additional characteristic of being counterintuitive in nature, thereby inducing cognitive conflict in the students. The online discussion provided students with an opportunity to work towards a shared resolution of the conflict.

Secondly, when the SOLO taxonomy was used to analyse the quality of student responses, it was found that more than 50% of the postings were assessed to be at the multi-structural, relational or extended abstract SOLO level, indicating that high level task oriented discussions are viable using an online learning platform. As with face to face discussions, however, the higher level comments are not necessarily made by all students. In the discussion analysed in this study, the mean SOLO level of responses for individual students varied from a low of 2.0 to a high of 4.0 (Table 3), indicating that the quality of some students' responses remained low throughout the discussion. In addition, no discernible increase was found in the quality level of student postings over time, indicating that online student learning may not follow a linear trajectory from low to high levels.

Thirdly, it was confirmed that the presence of the instructor in an online learning environment can be crucial to the level of engagement that students experience in the course. This sense of connectedness to the institution, through the instructor, can be a determining factor in student learning outcomes (Chin & Shen, 2004, Wu & Hiltz, 2004). Table 5 illustrates that for the course examined in this study, the instructors' input was generally restricted to low level questioning and reinforcing comments. Despite the lack of 'relational' level postings by the instructors, it is suggested that these comments do serve to maintain and generate student interest in the discussion (Figure 2). However, future research should focus on the impact that an active 'e-moderating' role can have in further enhancing student learning outcomes (Salmon, 2003).

Fourthly, it was found that in both the full time and part time group discussions, there was a distinct 'peak time' during which a high number of postings were made. It is reasonable to assume that any instructor contribution at this time may be crucial in shaping the subsequent debate. The active use of 'e-weaving', whereby the instructor selects discussion themes and rearranges them, making connections that may not have been intended by participants, may extend the 'peak' time of the discussion and increase the quality of any further student input (Salmon, 2003).

The design and management of virtual learning sites is of great interest to educators with the rapid increase in the number of online courses in recent years. In order to maximise the learning opportunities for students, it is essential that educators understand the dynamics of interacting in an online environment, and structure that environment to advance student learning. Not only should instructors ensure that online learning tasks are sufficiently open-ended, engaging and unambiguous, but they should also be familiar with the intricacies of managing online discussions and with viable methods of augmenting student learning within this framework.

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