An Analysis of Growth Patterns in Computer Conferencing Threads

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Abstract: Threads in a computer conferencing systems develop in seemingly unpredictable ways. Each time someone starts a new discussion or extends an existing line of thought, there is a subtle shift in the intellectual spotlight ñ a shift that influences the contribution patterns of subsequent users. Active threads may unexpectedly fade to the background, and older, inactive threads may regain centre stage. Yet within this complex ebb and flow, there are certain indicators that help predict a thread's future. An analysis of the 1571 threads in 7 distance education conferences reveals patterns of development that can be used to statistically assign growth probabilities to individual threads. Possible applications of these findings are discussed.

Keywords: computer-mediated communication, discussion forum

Introduction

Almost all conferencing forums make use of a process called *threading* to organize online discourse. A thread is a hierarchical arrangement of linked notes in which each successive contribution is written as a response to an earlier note in the discussion. Such structures have become an essential part of most email systems, web-based newsgroups, and computer conferencing packages. For educational purposes, threaded discourse offers an attractive, low-bandwidth means of delivering courses over the internet. Indeed, thousands of institutions currently rely on this technology, and its popularity is growing.

In this paper, we begin an analysis of the growth patterns of computer conferencing threads. Particular attention is paid to the problem of differentiating between active threads (i.e., threads that are in a state of growth) and threads that appear to have reached the end of their life span. At any one time in a computer conference there may be dozens of different threads at various stages of maturity. Some of the threads will be new, others will be in mid-development, and still others will have stopped growing. The first two of these stages are highly visible. The birth of a thread is marked by the addition of a new note to the conference. The development stage occurs when a chain of responses appears. However, the final stage of a thread's life span is difficult to discern. For example, suppose a thread has remained inactive for four consecutive days. Can it be assumed that the thread is dead? Or will it eventually grow even larger? At what point can it be claimed that an online discussion has ended?

Through this investigation, we hope to develop a deeper understanding of how threads evolve over time. We begin by constructing a day-by-day record of thread development. Using that data, we seek to establish a relationship between thread length, time, and the probability of future growth. The paper then explores the possibility of building new supports into computer conferencing packages that help learners more easily distinguish between active threads and those that are unlikely to produce further discourse.

The Data

This study examines seven graduate-level distance education courses containing a total of 4086 notes across 1521 distinct threads (Table 1). All courses were delivered using Web Knowledge Forum (WebKF), an asynchronous threaded discussion environment. The mean thread length across the courses was 2.69 (SD 3.01). The largest mean thread size was 4.20 and the smallest was 1.88. The variability in the means is likely due to differences in instructor experience, course requirements, and student practices.

Table 1: Thread count and mean size in seven distance education courses.

Course	Threads	Notes	Mean Thread Size
Course 1	144	271	1.88 (SD 1.46)
Course 2	365	817	2.24 (SD 2.88)
Course 3	245	665	2.71 (SD 3.38)
Course 4	100	420	4.20 (SD 3.63)
Course 5	244	524	2.15 (SD 2.12)
Course 6	245	841	3.43 (SD 3.43)
Course 7	178	545	3.06 (SD 3.12)
Overall	1521	4083	2.69 (SD 3.01)

The overall mean thread length of 2.69 is close to the value of 2.8 obtained by Guzdial (1997) in an earlier study. Guzdial's analysis reported a larger standard deviation (6.5), but his research examined threads from two different conferencing environments: CaMILE and internet newsgroups. The classes that used CaMILE had significantly longer discussions ($p<.001$, two-tailed test) than the newsgroup classes, and these differences undoubtedly amplified the variance.

The collective distribution of thread sizes in the seven courses (Figure 1) reveals a high proportion of small threads. Although the overall mean thread size is 2.69, the distribution is heavily skewed and both the median and the mode of the distribution are 1.0. Over 80% of the online discussions contain 4 notes or less. Thus, most of the threads are short and contain, at most, a few exchanges. In fact, over 50% of the threads (the threads of size 1) are not even discussions in the conventional sense, since they only consist of a single entry.

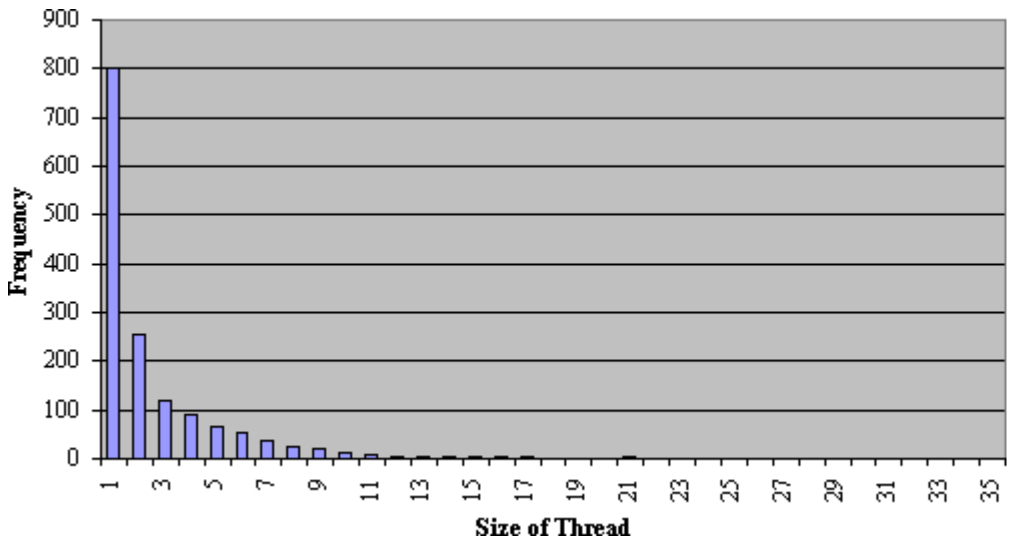

Figure 1: Frequency of thread sizes.

Patterns of responses to individual notes

Attempts to predict whether a particular thread will grow, or stop growing, can be informed by an analysis of online interaction patterns. At a fundamental level, thread growth occurs when someone responds to one of the thread's notes, thereby extending the discussion. What are the odds that someone will reply to a particular note? And how do these odds change over time?

In the seven graduate distance education courses examined, only 42% of the 4083 notes received a response. Figure 2 shows that 63% of the replies occurred on the first day (i.e., within 24 hours), 16% on the second day, 8% on the third day and 4% on the fourth. The cumulative sum of the probabilities for the remaining days (i.e., five, six, and so forth) is approximately 9%. Therefore, if a note fails to attract attention in the first few days, it is unlikely to receive any responses at all. These results are similar to those reported by Guzdial (1997) and Brett et. al. (1999) in their studies of online interaction.

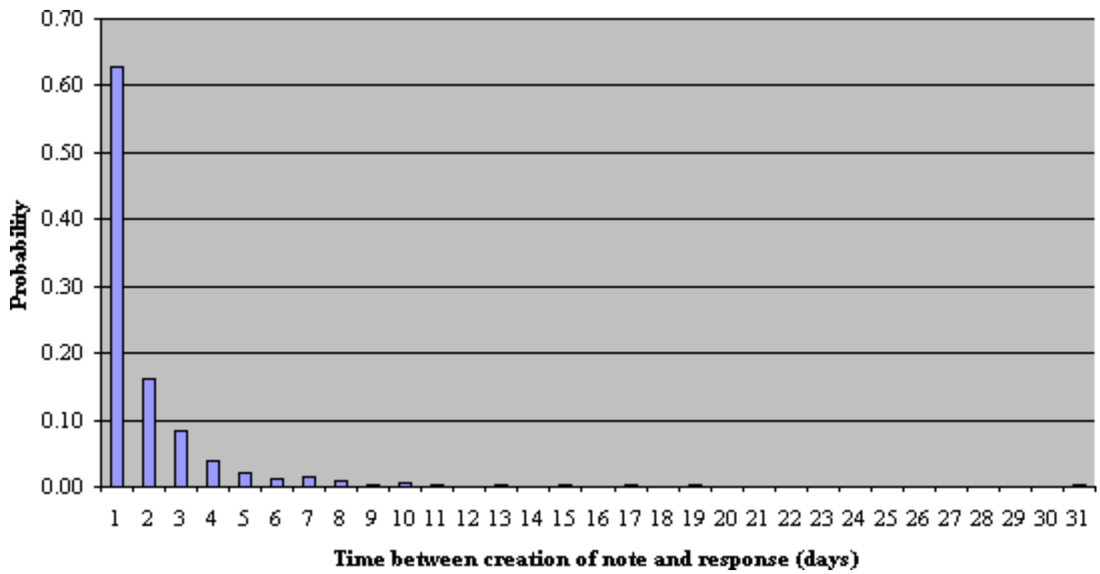

Figure 2: Probability that a note will receive a response.

The rapidly decreasing probabilities in Figure 2 suggest that the growth potential of a thread may depend, to some degree, on the age of its notes. For example, if all the notes within a thread are six or seven days old, then the opportunities for growth are limited. However, if all the notes were produced in the past 24 hours, the probability of further growth would be more promising.

Patterns of thread development

At first glance, it is tempting to use the results from Figure 2 to mathematically generate thread growth probabilities. For example, one could try to estimate the probability of a thread's growth by summing the probabilities of its constituent notes. Unfortunately, this approach is statistically problematic and can produce nonsensical results with large threads (e.g., probabilities that exceed 100%). How, then, can the Figure 2 findings be applied to entire threads rather than individual notes?

This paper calculates thread growth probabilities by analyzing the day-by-day evolution of online discourse. By understanding how threads develop over time, it becomes possible to create a probability table that takes into account the following information:

1. The time that has elapsed since the last note was added to the thread:

Figure 2 suggests that the odds of note receiving a response decrease over time. It is reasonable to assume that the probability of thread growth also decreases if the thread fails to grow over a period of several days.

2. The current size of the thread:

It is hypothesized that larger threads are more likely to inspire responses than small threads. For example, a thread of size 10 contains 9 more opportunities for writing a response than a thread of size 1.

The probability table is generated using a Bayesian analysis. The first step involves mapping out the history of each thread's development. This is accomplished by creating an array for each thread in which the array elements correspond to the number of notes saved on a given day. For example, Table 2 illustrates the day-to-day growth of Thread 17, a thread that ultimately reaches a size of 5 notes:

Table 2: The growth pattern of thread 17.

Thread 17: 1 1 0 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 END

The first element of this array represents the number of notes that were written on the day that the thread was established. In this case, 1 note was saved on the first day. The second element indicates that another note was saved on the second day. No notes appeared on the third day, but a single note was added on the fourth day, followed by two more notes on the fifth. At that point, the thread stopped growing and there was no further activity for the remainder of the course.

Using hundreds of such arrays, and Bayesian analysis techniques, it becomes possible to answer questions like,

> "What are the odds that a thread of size 2 is dead if two consecutive days go by in which the thread fails to develop?"

To answer this question, we identify all arrays that match the pattern:

> "thread size of two followed immediately by two consecutive zeroes"

For demonstration purposes we consider the small set of four arrays displayed in Table 3. Thread 14 matches the criteria on day 3. So does thread 15 on day 7 and thread 16 on day 6. Thread 17 does not match the criteria and so it is not considered in the calculation.

Table 3: The growth pattern of threads 14 to 17.

Thread 14: 2 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 END

Thread 15: 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 END

Thread 16: 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 END

Thread 17: 1 1 0 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 END

The data from threads 14, 15, and 16 suggest that on one occasion (thread 14) there was growth after a pair of zeroes was encountered. In the other two cases, the threads did not develop further. From this limited data set, we can fashion a crude estimate of the probability of future growth for a two-note thread after two consecutive days of inactivity:

P(future growth) = (# of matching threads that continue to grow) divided by (# of matching threads)

= 1 / 3

= 33%.

Applying this technique across 1521 threads in seven computer conferences yields the data presented in Table 4. The first value in each cell represents the number of times that a thread of a particular size continued to grow after experiencing the given period of inactivity. The second value represents the number of times that a thread failed to grow under the same conditions.

Table 4: Frequency values used for used for thread growth predictions.

Thread Size	0 Days (Active)		1 Day Inactive		2 Days Inactive		3 Days Inactive		4 Days Inactive		5 Days Inactive		6 Days Inactive	
1	282	763	**182**	**803**	112	803	75	803	56	803	47	803	34	803
2	236	233	108	254	68	254	43	254	28	254	21	254	14	254
3	202	119	77	121	41	121	23	121	18	121	16	121	12	121
4	131	91	44	89	32	89	19	89	13	89	10	89	8	89
5	104	69	46	66	30	66	14	66	11	66	9	66	7	66
6	66	51	29	52	11	52	7	52	7	52	6	52	4	52
7	47	36	19	36	8	36	7	36	3	36	3	36	2	36
8	33	25	14	23	6	23	5	23	3	23	2	23	1	23
9	26	20	8	19	6	19	4	19	3	19	1	19	1	19
10	17	14	5	13	3	13	2	13	1	13	1	13	0	13

For example (see boldface in Table 4), on 985 occasions, there was at least one day of inactivity after a single note thread was formed. On 182 of those occasions, the thread subsequently developed. On the other 803 occasions, the thread died.

The table also provides statistics for those occasions in which the number of inactive days was zero (i.e., the last growth spurt in the thread occurred within the past 24 hours).

Using the Table 4 information, the probability of future growth can be calculated by dividing the first value by the sum of the two values in each cell. The results are shown in Table 5.

Table 5: Probability of future thread growth given the thread size and the number of consecutive days without activity.

Thread Size	0 Days (Active)	1 Day Inactive	2 Days Inactive	3 Days Inactive	4 Days Inactive	5 Days Inactive	6 Days Inactive
1	.2699	.1848	.1224	.0854	.0652	.0553	.0406
2	.5032	.2983	.2112	.1448	.0993	.0764	.0522
3	.6293	.3889	.2531	.1597	.1295	.1168	.0902
4	.5901	.3308	.2645	.1759	.1275	.1010	.0825
5	.6012	.4107	.3125	.1750	.1429	.1200	.0959
6	.5641	.3580	.1746	.1186	.1186	.1034	.0714
7	.5663	.3455	.1818	.1628	.0769	.0769	.0526
8	.5690	.3784	.2069	.1786	.1154	.0800	.0417
9	.5652	.2963	.2400	.1739	.1364	.0500	.0500
10	.5484	.2778	.1875	.1333	.0714	.0714	.0000

The threads with the highest potential for future growth are those that were recently active (i.e., threads with zero days of inactivity). Multi-note threads that match this pattern have probabilities that exceed 0.5. After one day of inactivity, the odds that a single note thread will survive are 18.48%. After two days, this figure drops to 12.24%, and after 3 days to 8.54%. Notice that larger threads are more likely to endure periods of inactivity. After a single inactive day, a two-note thread will survive 29.83% of the time, and a three-note thread will survive 38.89% of the time. This finding is not surprising; larger threads contain more notes, and therefore offer participants more opportunities to write responses. However, the relationship between thread-size and probabilities is not linear (i.e., a twofold increase in a thread's size will improve, but does not necessarily double, the thread's chances of future growth). Also, the trend toward higher probabilities is limited. Once a thread contains more than five notes, the probabilities level off and then decrease. Figure 3 displays the Table 5 probabilities for threads containing 5 notes or fewer.

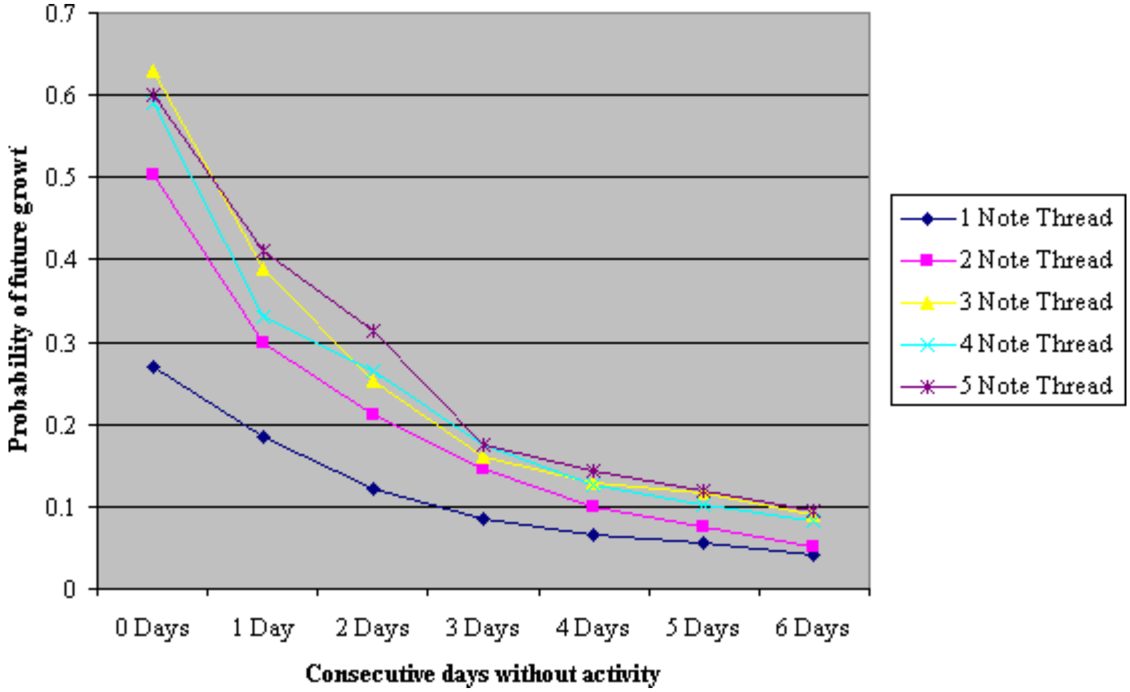

Figure 3: Probability of future thread growth for threads, size 1 through 5

To a certain degree, thread growth follows a "rich get richer" pattern. That is, threads of size 4 and 5 are more likely to grow than the smaller threads. However, the probabilities seem to level out, and then decrease, after threads reach a size of five (see Table 5). The reasons for this are unclear, but the following two hypotheses are offered:

Hypothesis 1: It is possible that people only reply to the three or four most recent notes in a thread. By the time a thread contains six or more notes, the first few notes in the thread are usually several days old. According to the Figure 2 distribution, the probability that such notes will inspire a response is extremely low. Therefore, the contribution made by old notes to the probability that the thread will grow is negligible. If this hypothesis is correct, then once a thread reaches a certain size, the probability of growth will not change substantially. All subsequent development would emerge out of responses to the three or four most recent arrivals.

The relationship between the length of a thread and its life span is illustrated in Figure 4. For the purposes of this paper, a thread's life span is defined as the time elapsed between the saving of the first note and the final note in the thread. Notice that the single-note threads have a life span of zero, since these threads start and end at the same time. In two-note threads, the mean time separating the first and last note is less than two days. As might be expected, larger threads tend to have longer life spans. These observations support the Hypothesis 1 assumption that the initial notes of larger threads will be several days old.

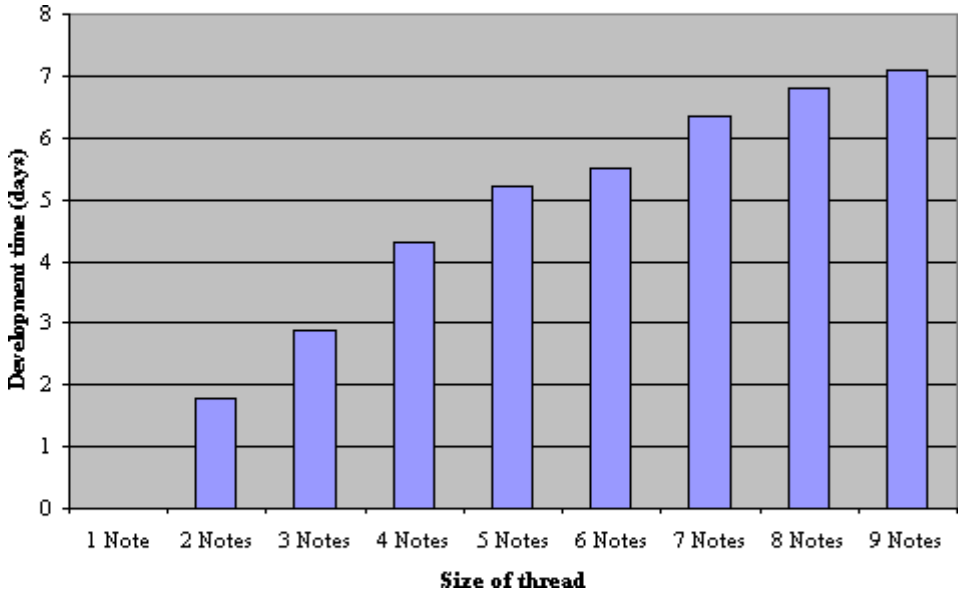

Figure 4: The relationship between the size of a thread and time of development.

Hypothesis 2: The leveling and gradual reduction of future growth probabilities (Table 5) may be partially an artifact of certain instructional practices. In some courses, students only explore a particular topic for a single week. At the end of that time, a new topic is introduced and a new conferencing area is created. Thus, each week, the class begins work in an empty conference, and the threads created previously are largely (but not completely) ignored. This practice imposes an artificial limit on the maximum size of a thread. Since larger threads may take a week or more to develop (see Figure 4), a nine-note thread that has experienced two days of inactivity is more likely to die than a five-note thread in a similar situation.

Additional research should be able to determine the degree to which weekly transitions limit thread development and decrease the growth probabilities for large threads. Hypothesis 1 may explain a tendency for probabilities to even out as the thread sizes increase. However, Hypothesis 2 better explains the slight decreases associated with large threads.

Future possibilities: Making growth probabilities available to learners

Growth probabilities, like the ones calculated in Table 5, could potentially be used to help online learners better distinguish between active and inactive threads. A number of different applications can be imagined:

1. Computer conferencing software could associate a growth probability with each thread and then display this information in some fashion. One simple approach is to show the

growth probabilities on the screen beside each thread. Alternatively, threads could be sequenced according to their probabilities (i.e., the most active threads are displayed at the top of the screen followed by less active threads).

2. Computer conferencing software could automatically archive, or otherwise remove from view, those threads that have low growth probabilities. Such threads could be still be accessed, but they would be located in a holding area that is separate from the active, ongoing discussions.

3. Using email, computer conferencing programs could automatically notify the creator of a thread if the thread's probability of growth drops below a certain threshold. This would provide users with the opportunity to rescue important discussions that are at risk of dying.

Each of the above interventions could change the way that online discussions develop over time. For example, the idea of ordering threads by their growth probabilities would presumably rank active 3-note threads ahead of active 1-note threads (because according to Table 5, the probabilities of growth are greater). Therefore, larger threads would appear at the top of the screen, while smaller threads may require scrolling to access. Presumably, this would reinforce the rich-get-richer phenomenon, resulting in even larger threads. At the same time, small 1-note threads would be less visible, and would have more difficulty becoming established. The educational ramifications of such a design are unclear.

One practical impediment to the implementation of the aforementioned strategies concerns the computation of the growth probabilities. The values displayed in Table 5 were calculated using 7 graduate distance education conferences. While these values may serve as a reasonable starting point for some applications, they are inadequate in two respects:

1. The shape of the probability curves will be affected by the number of course participants, the course requirements, and the resulting activity level. A course containing 100 people who participate daily will require different probability curves than a course containing 4 people who participate once a week.

2. Making users aware of the growth probabilities may give rise to new behaviors that make the posted probabilities inaccurate. For example, people may start ignoring threads that have low scores. Such behavior would further reduce the odds of these threads surviving. In general, the display of probabilities may change student practices, resulting in the reduction or amplification of the actual probabilities.

Solving the above problems requires the development of dynamic, adaptive algorithms that continually tailor the growth probabilities to the conditions of the course and the behavior of the participants. We have not yet developed such an algorithm, but we are investigating the possibility of using participant reading and writing patterns to progressively fine-tune probabilities.

Conclusions

The lifecycle of a thread is only partially evident to users of computer conferencing environments. The birth of a thread is an obvious event, but it is impossible to determine if a thread has died until after the conference draws to a close. At that point, one can look back and identify the date that the thread stopped growing (i.e., the date of the last contribution to the thread). However, while the conference is still in progress, the status of all threads is uncertain. A particular discussion may already be as large as it is destined to become, or it may develop further in the coming days and weeks. Consequently, there is always ambiguity concerning the fate of any particular thread.

In this paper, we examine the day-by-day evolution of 1521 threads in seven distance education courses. The following observations were made:

1. Most of the threads are small. Over 80% of the threads contain four notes or fewer.

2. Notes acquire most of their responses in the first few days after they are initially posted to the conference. The odds of a response drops dramatically with time.

3. The longer that a thread has been inactive, the greater the chances that the thread will remain inactive until the end of the conference.

4. The probability of a thread's growth is related to the thread's size. Probabilities increase with thread size until the thread contains five notes. Subsequent growth yields slightly reduced probabilities.

Using the above findings, it may be feasible to develop algorithms that dynamically compute growth probabilities and make them available to online learners. Such supports would allow conference participants to more easily determine whether a particular discussion is likely to develop further, or whether it has already run its course. Such systems could alert authors when important threads appear to be dying. These kinds of interventions would likely result in new learner behaviors ñ behaviors that will change the probabilities that underlie the interventions. Therefore, it may be necessary to develop algorithms that continually adapt to match the changing patterns of communal discourse.

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Bibliography

Brett, C., Woodruff, E., and Nason, R. (1999). *Online community: What can reading and writing patterns tell us about participation?* Paper presented at the annual meeting of the American Educational Research Association, Montreal Canada.

Guzdial, M. (1997). *Information ecology of collaborations in educational settings: Influences of tool*. In the proceedings of the Computer Support for Collaborative Learning conference, CSCL'97, Toronto Canada, 83-90.

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